

OSLO AND AKERSHUS
UNIVERSITY COLLEGE
OF APPLIED SCIENCES



Emília de Carvalho Garcia Monteiro Tavares

Ontologies for Digital libraries

Master thesis
International Master in Digital Library Learning
2015

Abstract

The amount of information available in both printed and electronic formats has increased dramatically in recent years. This rapid growth of information in the modern world leads people and especially the organisations that deal with such information to be organized in order to facilitate access, although standard library classification schemes are used to accomplish this goal, some flaws that are inherent in natural languages, may create severe issues in the process of classification. Hence it affects the likelihood of finding a document as well as affecting the time and effort spent organising the material. Moreover, the amount of digital documents are rapidly increasing and require easy and accessible mechanized methods (Gamage and Wijewickrema, 2013).

In the same way, the digital library domain as a field of study has grown quite significantly during the last two decades. Because of its interdisciplinary nature, the digital library domain involves a large number of concepts which should be captured, classified, structured and created into digital library ontologies. Therefore, ontologies have the potential to play an important role in this field, because an ontology defines a common vocabulary for researchers who need to share information in a domain. Such ontology can be used for digital library collaboration, interoperation, research, education, and modelling. However, a large number of ontologies have been developed by different groups, using different approaches, different methods and techniques, but not in the Digital Library domain, specifically using the Reference Model proposed by Delos.

This study aims to harness the collective knowledge within communities in digital libraries, improving the discovery and dissemination of knowledge through ontologies. The methodological guidelines presented in this research have been created in the context of the Methontology approach, our demonstration illustrates the creation in SKOS of the Digital library reference model (DLRM) proposed by Delos. With this we can better organize, share and discover knowledge using ontologies.

Keyword: Digital libraries, References Model, Ontology, Digital Library References Model, Delos References Model, SKOS.

Acknowledgement

First, I would like to express my gratitude to God for being my strength and guidance in my academic pursuits.

Then, I would also like to express sincere gratitudes to my family, especially my husband and my kids for the unconditional support, for understanding the reasons for my absence and for being my relief at times when this thesis proved a challenge that went beyond my normal routine. And also a big thank you to my mum for supporting me and always being there for me and also to my dear mother-in-law for her support to my family while I was away.

A thank you to my colleagues, but especially Ana Pervan for all the help and patience and Meghan King.

A thank you to my supervisor, Vittore Casarosa, as well as my coordinator, Anna Maria Tammaro, for all the help and support.

My colleagues for always pushing me to conclude this chapter in my academic journey.

For all who directly or indirectly contributed to make it a reality, than you so much.

LIST OF ACRONYMS

DL – Digital Library

DLMS - Digital Library Management System

DLRM - Digital Library Reference Model

DLs - Digital Libraries

DLS – Digital Library System

ICT - Information and Communication Technology

ICTS - Information and Communication Technologies

KOS - Knowledge Organization Systems

OWL - Web Ontology Language

RDF - Resource Description Framework

RF – References Model

SKOS - Simple Knowledge Organization System

W3C – World Wide Web Consortium

XML - Extensible Markup Language

Glossary of terms:

5S - is a framework for providing theoretical and practical unification of digital libraries using 5 (five) components: Streams, Structures, Spaces, Scenarios, and Societies.

Concept - Concepts are the units of thought, ideas, meanings, of objects and events which underlie many knowledge organization systems. Concepts exist in the mind as abstract entities which are independent of the terms used to label them («Simple Knowledge Organization System», 2015).

Controlled vocabulary - is an organized arrangement of words and phrases, to provide a way to organize knowledge used to index content and/or for subsequent retrieval through browsing or searching. It typically includes preferred and variant terms and has a limited scope or describes a specific domain. (Trust, 2009 and «Controlled vocabulary », 2015).

Digital Library (DL) - are organisations that provide the resources, including the specialized staff, to select, structure and offer intellectual access to interpret, distribute, preserve the integrity and ensure the persistence over time of collections of digital works (DFL,1998).

Digital Library Management System (DLMS) - is a generic software system that provides the appropriate software infrastructure both to produce and administer a Digital Library System, as well as to integrate additional Software Components offering more refined, specialised or advanced functionality (Candela et al., 2011).

Digital Library Reference Model (DLRM) - is a result of consolidation and enhancement activities, performed in the framework of the DL.org project.

Digital Library System (DLS) - a software system based on a given architecture and providing all the functions required by a particular DL.

Extensible Markup Language (XML) - is a markup language that defines a set of rules for encoding documents in a format which is both human-readable and machine-readable. It is a flexible way to create common information formats and share both the format and the data on

the World Wide Web. XML is a formal recommendation from the W3C («Extensible Markup Language », 2014).

Knowledge Organization Systems (KOS) - is a generic term used in knowledge organisation about authority lists, classification systems, thesauri, topic maps, ontologies and etc. («Knowledge Organization Systems », 2015).

Linked data - linked data describes a method of publishing structured data so that it can be interlinked and become more useful through semantic queries. It builds upon standard Web technologies such as HTTP, RDF and URIs, data from different sources to be connected and queried («Linked Data », 2015).

Ontology - is an organised way of designing, categorising, helping and explaining the relationships between the various concepts in the same area of knowledge domain and research.

References Model - is an abstract framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment.

Resource Description Framework (RDF) - is a standard model for data interchange on the Web. It has features that facilitate data merging even if the underlying schemas differ, and it specifically supports the evolution of schemas over time without requiring all the data consumers to be changed (W3C, 2004).

Resource Description Framework schema (RDFs) - provides a data-modeling vocabulary for RDF data. RDF Schema is an extension of the basic RDF vocabulary.

Semantic Web - is a Web of Data. This data can be dates and titles and part numbers and chemical properties and any other data one might conceive of. The collection of Semantic Web technologies (RDF, OWL, SKOS, SPARQL, etc.) enables people to create data stores on the Web, build vocabularies, and write rules for handling data and also, provides an environment where application can query that data, draw inferences using vocabularies (W3C, 2014)

Simple Knowledge Organization System (SKOS) - is a World Wide Web Consortium (W3C) recommended standard for representing and publishing Knowledge Organization Systems

(KOS) on the Web, using a vocabulary and data model expressing Knowledge Organization Systems (KOS's) such as thesauri and classification schemes for referencing and re-use in Semantic Web applications (W3C, 2009)

Taxonomy - in general mode it is the practice and science of classification of things or concepts, including the principles that underlie such classification; basically it is a controlled vocabulary organized in a hierarch («Taxonomy », 2015).

Thesaurus - is a reference work that lists words grouped together according to similarity of meaning or in order words it is taxonomy with more information about each concept including preferred and alternative terms. Additionally a thesaurus may contain relationships to related concepts («Thesaurus », 2015).

Web Ontology Language (OWL) - is a language for defining and instance ontologies in Web. This includes descriptions of classes and their properties and their relationships. OWL was designed for use by applications that need to process the content of information, instead of just presenting it to humans. It further facilitates the possibility for interpretation by machines of Web content by providing additional vocabulary with a formal semantics. OWL is a W3C recommendation («Web Ontology Language », 2014).

World Wide Web Consortium (W3C) - is an international community that develops open standards to ensure the long-term growth of the Web.

Table of Contents:

ABSTRACT.....	iii
ACKNOWLEDGEMENT.....	iv
LIST OF ACRONYMS.....	v
GLOSSARY OF TERMS.....	vi
TABLE OF CONTENT.....	ix
LIST OF TABLES.....	xi
LIST OF FIGURES.....	xii
1 Introduction.....	13
1.1. Background.....	13
1.2. Statement of the Problem.....	16
1.3. Aim and objectives	17
1.4. Methodology research.....	18
1.5. Limitation of the research	18
1.6. The structure of this thesis	19
Chapter 2 Literature Review	21
2.1. Digital Library	21
2.2. Digital library challenges	23
2.2.1. Digital preservation.....	23
2.2.2. Metadata creation.....	24
2.2.3. Copyright and license	25
2.3. Digital Libraries Reference Model	27
2.3.1. Ontologies in Digital Library	27
2.3.1.1. Ontologies	28
2.3.2. References model for Digital Library	30
2.3.2.1. (5S) Formal framework.....	32
2.3.2.2. Open Archival Information System (OAIS).....	35
2.3.2.3. DELOS - Digital Library Reference Model.....	37
2.3.3. Comparison between Delos References Model and 5s.....	42
Chapter 3 Methodology of reserach.....	45
3.1. Theoretical Bases	46
3.1.1. Qualitative methodology.....	46
3.1.2. Exploratory Research.....	47
3.1.3. Case Study	47
3.1.4. IEEE Standard 1074-2006	48
3.2. Justify the research methodology chosen	49
3.3. Methontology	50
3.4. Ontology life cycle.....	51
3.4.1. Specification	52
3.4.2. Conceptualization	53
3.4.3. Formalization	56
3.4.4. Implementation	57
3.4.5. Maintenance.....	57
3.4.6. Evaluation	57
Chapter 4 Designing and Implementation	59

4.1.	Introduction.....	59
4.2.	Process for building the ontology	60
4.2.1.	Ontology capture.....	60
4.2.1.1.	Concepts and Relationships	60
4.2.2.	Process to Ontology encoding	76
4.2.2.1.	Tools and languages.....	76
4.2.2.1.1.	SKOS - Simple Knowledge Organization System.....	79
4.2.2.1.2.	Poolparty	83
4.3.	Implementation	83
4.3.1.	Main components of Digital Library SKOS representation	83
	Conclusion and future work.....	90
	References.....	92
A	Appendix.....	104
A.1	Digital Library References Model represent in SKOS	104
A.1.1	Digital Library Domain and their top concepts	104
A.1.2	Main Concepts	104
A.1.3	Associative Relations.....	105
A.1.4	Hierarchical Relations.....	107
A.1.4.1	Digital Library	107
A.1.4.2	Digital Library System.....	108
A.1.4.3	Digital Library Management System.....	109
A.1.4.4	Resource.....	110
A.1.4.5	Information Object.....	112

List of Tables

Table 1 - Comparison between Ontology Editors.....78

List of Figures:

Figure 1 - 5S Definition structure	33
Figure 2 Example of 5S supported DL	35
Figure 3 - OAIS Functional Entities	36
Figure 4 - Delos Digital Library Model	39
Figure 5 – A three-tier Framework (DL, DLS and DLMS).....	39
Figure 6 - Main concept in the DL universe	41
Figure 7 – Delos References Model.....	42
Figure 8 - 5S framework and Delos References Model.....	44
Figure 9 - Methontology ontology development process life cycle	51
Figure 10 - Ontology requirements specification in the Delos References Model domain.....	53
Figure 11 - Task of conceptualization process	54
Figure 12 - Concept classification hierarchy	56
Figure 13- The Users Concepts.....	56
Figure 14 - The Reference Model Concepts	59
Figure 15 - DL Resource Domain Concept Map	64
Figure 16 - Content Domain	66
Figure 17 - User Domain concept maps	67
Figure 18 - Functionality Domain Concept Map.....	68
Figure 19 - Policy Domain.....	69
Figure 20 - Quality Domain Concept Map	70
Figure 21 - Architecture Domain Concept Map	71
Figure 22 - Ontology languages.....	77
Figure 23 - Main elements of the SKOS data model	80
Figure 24 - Digital Library Ontology Domain concepts in PoolParty.....	84
Figure 25 – Statistics page in PoolParty	89

1 Introduction

This chapter will address a general topic in the research, providing the background of information and communication technology (ICT), digital libraries (DL), ontologies and references models (RF), followed by the Statement of the Problem, where we show the reason for this research being carried out; as well as the aim to understand if Delos reference model theoretical models can represent several DL. To achieve the aim, these objectives have been set: analyse Delos References model and to produce an ontology of Delos reference model to see if Delos reference model is a ideal model to represent digital libraries, the methodology to achieve the research aim is a combination of qualitative exploratory research methodological approach as mode of investigation and also a technical approach, using the case study as a method of the research we will see if methontology as a methodology can build the Delos References Model ontology and the structure of the thesis where we explain how this research is structured.

1.1. Background

“(...) Digital Library universe is a complex world. Consequently, it is difficult to identify a single and fully-fledged model capable of capturing all the aspects needed to represent this universe in all the necessary scenarios (...)” (Athanasopoulos et al. 2010). (...) “Digital libraries may be extremely complex information systems. The proper concept of a digital library seems hard to completely understand and evades definitional consensus (...)” (Gonçalves, 2004).

Over the last decade, the increasing use of Information Technologies and Communication Technologies (ICTs) has driven a new range of information needs. Digital environments provide transposition conventional limits of representation and knowledge dissemination of information, it adds new elements to the production processes, organisation and retrieval of information has caused a demand for tools and methods to meet the new emerging information needs. New challenges are always arising within the area of information science, so that the development of digital libraries deserves special attention due to large impacts suffered in what is more concrete and significant libraries, until very recently the collections they formed only by tactile objects and now also covering electronics, volatile documents, consisting of bits and bytes of information (López, 1999 and Ramalho, 2010).

Nowadays, we find new types of libraries coming up from long-term personal digital libraries, as well as digital libraries that serve specific organisations, educational needs, and cultural

heritage and that vary in their reliability, authority and quality. Exponential growth of data available has given significant importance to techniques of organizing information and various types of structures (glossaries and dictionaries, as well as taxonomies and still ontologies, the thesaurus and semantic networks) are used in information organization, acting in its selection, in its processing, its recovery and its dissemination. The collections are becoming more heterogeneous in terms of their creators, content, media, and communities served and also the user communities are becoming heterogeneous in terms of their interests, backgrounds, and skill levels, ranging from novices to experts in a specific subject area (Almeida & Bax, 2003; Sheth et al., 2005 and Ferran & Minguillón, 2005).

However, optimizing the management processes of information resources, has becoming increasingly complex, since the task of developing and managing digital libraries, has become too complex, particularly because of their elusiveness and multiplicity of related technologies and information resources available in digital environment. Nevertheless, the increasing number of data sources available hampers the retrieval of information. In the current context of explosive availability of data, there is a need for a knowledge discovery approach, based on both top-down knowledge creation (e.g., ontologies, subject headings, user modelling) and bottom-up automated knowledge extraction (e.g., data mining, text mining, web mining) (López, 1999; Ferran & Minguillón, 2005; Morais & Ambrósio, 2007; Ramalho, 2010 and Nguyen, 2013).

In recent years this led to several studies emphasizing the use of ontologies as an alternative to the organization of information, in order to better meet the information needs, transform the traditional services into digital ones to a new handicap where the next generation of libraries should be more proactive offering personalized information to their users taking in consideration each person individually and thus transfer DL an institution data and information into an institution of knowledge (López, 1999; Ferran & Minguillón, 2005; Morais & Ambrósio, 2007; Ramalho, 2010 and Nguyen, 2013).

The development of new information technologies and infrastructures, such as the World Wide Web, requires new ways to create, manage, publish and use information. Knowledge organisation systems, such as taxonomies, thesauri, ontologies or subject heading lists and even folksonomies, play a fundamental role in information structuring and access (W3C, 2009).

Therefore, it is necessary to build a complete and complex structure for describing all the richness of the possible scenarios of use of the DL and the relationships which can be established among

all the participants, ontologies are a powerful tool for describing these scenarios, where several concepts and relationships between these concepts can be identified and formally represented. Ontologies promote the integration of new services into existing ones, and the interoperability with other systems through the appropriate semantic web services (Sheth et al., 2005; Ferran and Minguillón, 2005).

Ontologies are used today in many areas (philosophy, artificial intelligence, knowledge-based systems) to organize information, several definitions of the ontologies are found in the literature, several types proposed for application in different areas of knowledge and proposals for building ontologies (methodologies, tools and languages). But what matters for this study is the ontology in the context of semantic web, the ontology is used a basis for enabling interoperability through the semantic web. So, an ontology is taking the meaning adopted by the semantic web community, a formal description of a possible scenario or context; that is, what “exists” is what can be represented by an ontology, using classes, relations, functions etc, with text describing what the names mean, and formal axioms that constrain the interpretation and use of these terms. A large number of ontologies have been developed by different groups, under different approaches, and with different methods and techniques with different scope, purpose and requirement (Bax & Almeida, 2003; Ferran & Minguillón, 2005 and Nguyen, 2013).

The reasons why we need ontology are:

- To share common understanding of the structure of information among people or software agents - one of the more common goals in developing ontologies;
- To enable reuse of domain knowledge - one of the driving forces behind recent surge in ontology research;
- To make domain assumptions explicit - explicit specifications of domain knowledge are useful for new users who must learn what terms in the domain mean, underlying an implementation makes it possible to change these assumptions easily if our knowledge about the domain changes;
- To separate domain knowledge from the operational knowledge - a common use of ontologies, we can describe a task of configuring a product from its components according to a required specification and implement a program that does this configuration independent of the products and components themselves;

- To analyse domain knowledge - possible once a declarative specification of the terms is available. Formal analysis of terms is extremely valuable when both attempting to reuse existing ontologies and extending them (Noy & McGuinness, 2001 and Nguyen, 2013).

The purpose of developing an ontology in this research is to build ontology about Delos References Model to DL in order to represent as many as possible DL's; to serve this purpose, this ontology is developed where the scope includes DL, DLS, and DLMS and all the main concepts: Content, Users, Functionalities, Quality, Policies and Architecture, and also relationships and rules of Delos References Model, using a formal level of formality the users and end-users are DLs users and Digital Librarians.

1.2. Statement of the Problem

The Digital Library Reference Model (DLRM) is a result of consolidation and enhancement activities performed in the framework of the DL.org project. The DL.org is the first initiative to investigate DL interoperability from an innovative, all-encompassing approach by harnessing the global expertise that exists in the field. The main outputs of DL.org for DL interoperability, best practices and reference modelling have been captured in 4 (four) user-friendly booklets to facilitate the community of professionals, students and researchers.¹ It introduces the principles governing such a model as well as the set of concepts and relationships that collectively capture the intrinsic nature of the various entities of the DL universe.

Connections with similar activities carried out by other research groups and initiatives at an international level will be established in order to achieve a global and stable level of consensus on the model, but is difficult establish a consensus because they concern several different areas, which makes it difficult to compare or combine the results achieved in these areas since it's not always clear how they are related, and how they can impact on or constrain one another (Athanasopoulos et al. 2010; Candela et al., 2011 and Delos, 2013).

Nguyen (2013) in her research on Digital Library Research Trends she said that DL have been discussed in various international digital library conferences, i.e. Joint Conferences on Digital Libraries (JC DL), The European Conference on Research and Advanced Technology for Digital Libraries (ECDL), International Conference on Asia-Pacific Digital Libraries (ICADL),

1

<http://www.dlorg.eu/blog/> access in September, 15 2014

etc, also there is so much research in different areas (digital library architecture, systems, tools, and technologies; digital content and collections; metadata; standards; interoperability; knowledge organization systems; users and usability; legal, organizational, economic, and social issues) presented an overview of trends in digital library research, but to date, to the best of the researcher's knowledge, there has not been any study that predicts the future of research in the digital library field.

Due to the variety of rich content that increase web and DLs, there exists the need for a formal model because we have several models developed by various entities, but these models lack of attention to the formal principles without a clear statement of entities and relationships needed.

The main reason for this problem is perhaps the lack of a knowledge map of the entire field of digital library research. Digital libraries need a corresponding RM in order to consolidate the diversity of existing approaches into a cohesive and consistent whole, to offer a mechanism for enabling the comparison of different systems, to provide a common basis for communication within the DL community and to help focus further advancement (Lenzerini et al., 2004 and Noy and McGuinness, 2001).

In 2005 the DELOS Network of Excellence on Digital Libraries decided to initiate the definition of a reference model for DLs as a necessary step towards a more systematic approach to the research on digital libraries (Athanasopoulos et al., 2010).

In this context almost a decade after de DL.org initiative, we want to explore how DLRM proposed by Delos can contribute to enrich DL ontologies. Many ontologies have been created and published in different areas and with different purpose, but ontology in DL fields is missing. Wherefore the main research problem is a lack of a digital library ontology that can be used for a variety of purposes.

1.3. Aim and objectives

The DELOS Digital Library Reference Model aimed at addressing major entities and their relationships in the DL universe following two mainly aim:

- define unifying and comprehensive theories and frameworks over the life-cycle of DL information;

- build interoperable multimodal/multilingual services and integrated content management ranging from the personal to the global for the specialist and general population (Casarosa, 2007).

The purpose of this research is to understand if the Delos reference model theoretical models can represent several DLs. i.e., if the purpose of Delos Model references mentioned above works in practice.

In order to achieve the research aim, these objectives have been set:

1. Analyse The Delos References model;
2. Produce an ontology for the Delos reference model using SKOS.

1.4. Methodology research

This study has adopted a combination between qualitative exploratory research methodological approach as a mode of investigation and a technical approach, using the case study as a method of the research and also methodology as a methodology inside a case study aimed to build the Delos References Model ontology.

The literature review, both on theoretical articles, with an inter-disciplinary bibliography (mainly involving the areas of Library, DL, Information Science, Computer Science, references model and ontology), seeking the establishment of the theoretical and conceptual framework for the research.

The theoretical basis as well as the justification of the chosen methodology will be properly treated in chapter methodology for the development of research.

The Delos References Model ontology methodology is constructed as follows: analyse the conceptual model and convert the conceptual model to Computational model. Chapter 3 provides the justification and explanation of the methodology chosen for this research.

1.5. Limitation of the research

Regarding the design and implementation of any study there are certain inherent limitations, once the domain of study is embracing and we need to focus on one part of each area. The methodology chosen for the purpose of this research allows the representation of digital library ontology in SKOS, although the choice of the methodology may not be the most appropriate since there are

many to choose from and since there is lack of ontologies for digital libraries which have a variety of purposes it is difficult to have a model that can be based and also, in this case the representation of the Delos reference model. The lack of bibliographic resources in this specific domain (Delos RM) will limit to the topic about Delos references model to three authors: Casarosa (2007), Athanasopoulos et al. (2010) and Candela et al. (2011).

Because of my geographic location (Cape Verde) during the research, limit the resource bibliography to: articles, book chapter and scientific journals found online, because Cape Verde has serious problems with the acquisition of bibliographic resources and scientific production is deficient, in this specific case: ontology the resources are not deficient but non-existent, this prove be one limitation to this research.

However, they have served the purpose of applying the method and analysing results sufficiently in order to answer the research question. The justification for choosing this specific methodology for build Delos RM and some further limitations concerning the implementation are stated in Chapter 3 and 4.

1.6. The structure of this thesis

Introduction provides the background of the research topic and statement of the problem. This is followed by a short introduction about DL, their needs and challenges and also about ontologies. It includes the methodology chosen for this study, aim and specific objective, the limitation of research and finally the structure of this thesis.

Chapter 1: Literature Review is dedicated to exploring the DL and its challenges, and also to explore the ontologies. It is built in a form of a theoretical framework that should help conducting this study. The important parts of this literature review also trying to find the concepts and relationship of Delos in this "modern" DL.

Chapter 2: Methodology describes the methodology chosen to implement this study and provides a justification for that choice. The methodology is a combination between qualitative exploratory research methodological approach as a mode of investigation with a technical approach, using the case study as a method of research and methontology as a methodology to build the Delos References Model ontology. Some tools like SKOS and PoolParty are also used.

Chapter 3: Designing and Implementation, presents the process of creation the Delos References Model in SKOS using the tool PoolParty.

Conclusions and future work, offers conclusions to the research question presented at the beginning of the thesis. Offers a contribution to RM to DL in the ontology fields. Finally, some suggestions are made for the directions that might be taken by future researchers focusing on this topic.

Chapter 2 Literature Review

In this chapter DL, their needs and challenges, as well as ontology definition and fields and the various models of references will be addressed with particular emphasis on Delos References Model which is the purpose of the research.

2.1. Digital Library

“Digital libraries are a set of electronic resources and associated technical capabilities for creating, searching and using information, (...) they combine the structure and gathering of information, which libraries and archives have always done, with the digital representation that computers have made possible(...)” (...) the main purpose of a digital library is to collect, manage and preserve in perpetuity digital content (...) (Casarosa, 2010 and Candela et al., 2011).

In modern times, the development and proliferation of digital libraries is giving rise to momentous transformations in the generation, access, utilization, dissemination and also the management of information resources, the introduction of a novel technology, such as digitization of information resources, tends to warrant a number of training requirements is required, and also the way we represent the information, because the needs change with the novel technology, it is necessary, in order to promote the openness and speed that normally accompanies such new technologies, of which digital libraries are included. (Ongus et all, 2007).

The history of DL is relatively short. Although a discussion of digital libraries began in the 1960s, but only in the mid-1990s, the research, development and practice related to digital libraries really began. The growth was extraordinary, in just over a decade thousands of digital libraries in various forms were built and are operating globally, with many more to come (Saracevic, 2004). According to Libweb (2014) a directory of libraries on the web maintained by University of California, Berkeley, there are currently more than 8,000 pages of digital libraries in 146 countries, covering all continents.

Consonni (2011) in their studies seek to define the DL it said that for years many professionals and organisations have dealt with the difficult task of providing a single definition for all these experiences, unfortunately, without reaching an agreement, and Schwartz (2000) listed more than 64 different definitions from students attending a course of digital Libraries and the tendency to examine the research in this area is increasing.

However, the DLF (Digital Libraries Federation) in 1998 defines digital libraries as: "Digital libraries are organisations that provide the resources, including the specialized staff, to select, structure, offer intellectual access to, interpret, distribute, preserve the integrity of, and ensure the persistence over time of collections of digital works so that they are readily and economically available for use by a defined community or set of communities" (DLF, 1998 and Walters, 1998).

Common features ace digital libraries go through:

- Provide round the clock services to users, within and without the library environment. Users can access the digital objects at anytime and anywhere i.e. 24 hours and 7 days a week with only a computer and internet connection;
- Provide a coherent view of all information contained within a library, no matter its form or format (eg, text, audio, image and video);
- Several users can access a digital object at the same time in different locations;
- Digital libraries do not require large spaces, unlike traditional libraries where physical space is required for the construction and maintenance of the collections. (Isah et al., 2013).

These Common features show the flexibility, portability, and accessibility of Digital libraries.

Nevertheless, the principles underlying the functionality of digital libraries were simple, the premise that digital libraries dealing with traditional problems of searching for information delivery to users and to preserve it for posterity. Digital information takes up less space than information on paper and therefore, can help traditional libraries reduce costs is no longer enough anymore, so many more models are defined to meet specific needs that will be stumbling over time and with changing new technologies.

Nevertheless, the principles underlying the functionality of digital libraries were simple, the premise that digital libraries dealing with traditional problems of searching for information delivery to users and to preserve it for posterity. Digital information takes up less space than information on paper and therefore, can help traditional libraries reduce costs is no longer enough anymore, so many more models are defined to meet specific needs that will be stumbling over time and with changing new technologies.

As we can see from the statistics of Libweb (2014), hundreds of research projects have been devoted in many aspects to digital libraries in many countries, and more are reported each year. All this information about digital libraries is explosive, which makes it difficult to have a reference model enabling one to represent succinct clear digital libraries. Nevertheless, the “ideal model” does represent all DL is difficult to establish the consensus because, they concerns several different areas, which makes it difficult to compare or combine the results achieved in these areas since it's not always clear how they are related, and how they can impact on or constrain one another, like already said before (Saracevic, 2004; Ongus et al., 2007 and Athanasopoulos et al., 2010).

2.2. Digital library challenges

Although digital libraries have a short story, since the research, development and practices relating to digital libraries are recent however, technology changes and increasing digital demand makes digital libraries face a number of challenges in various areas such as preserving, copyrights and licenses and also creating metadata. Not only are these the challenges they face, but these are the most challenging and a brief description of each of these largest challenges will be made in the paragraphs below.

2.2.1. Digital preservation

“Digital preservation is now everyone’s problem” (Harvey, 2005).

Preserving digital content for long term is important safeguarding our intellectual heritage so that it can be used by future researchers. The rapid rate at which technology is evolving and the relative transience of digital content make this a significant challenge, because rapid changes have threatened the continuity of access to digital content. Unlike traditional analogy objects such as books or photographs where the user has unmediated access to the content, a digital object always needs a digital environment to render it available (Muir, 2003; Harvey, 2005; «Digital Library», 2014 and «Digital preservation», 2014).

The purpose is to ensure protection of information of enduring value for access by present and future generations, in this sense libraries and archives have served as the central institutional focus for preservation and in recent decades, have established formal preservation programs for traditional materials which include regular allocation of resources for preservation, preventive measures to arrest deterioration of materials, remedial measures to restore the usability of

selected materials, and the incorporation of preservation needs and requirements into overall program planning. All this serves the same purpose; preserve it for access by present and future generations (Muir, 2003; Harvey, 2005; «Digital Library», 2014 and «Digital preservation», 2014).

In the case of born-digital content (e.g., institutional archives, Web sites, electronic audio and video content, born-digital photography and art, research data sets, observational data), the enormous and growing quantity of content presents significant scaling issues to digital preservation efforts, because these environments keep evolving and changing at a rapid pace, threatening the continuity of access to the content, this is due a physical storage media, data formats, hardware, and software all become obsolete over time and quickly (Hedstrom, 1997; Harvey, 2005; «Digital Library», 2014 and «Digital preservation», 2014).

But preserving is not the only challenge. How to preserve it is a challenge that can be even higher, since digital content because of nature is complex and dynamic (e.g. interactive web pages, games and virtual reality environments), becomes a problem due to emerging technological advances, authenticity, integrity and fixity of objects over time resulting from certain technologies that may be more robust (Hedstrom, 1997; Harvey, 2005; Hanna, 2013 and «Digital preservation», 2014).

Another challenge of preserving digital content around lies in the question of scale. The amount of digital information being created along with the proliferation of format types makes the creation of trusted digital repositories with adequate and sustainable resources a challenge. The Library of Congress is a great example, currently amassed 170 billion tweets between 2006 and 2010 totalling 133.2 terabytes and each Tweet is composed of 23 fields of metadata. The economic challenges of digital preservation are also great, since preservation programs require investment. (Hedstrom, 1997; Harvey, 2005; Hanna, 2013 and «Digital preservation», 2014).

2.2.2. Metadata creation

“In traditional libraries, the ability to find works of interest is directly related to how well they were catalogued” («Digital library», 2014).

The word “metadata” means “data about data”. Metadata articulates a context for object of interest, “resources” such as MP3 files, library books or images, in the form of “resource

description” («Metadata», 2014). It is machine understandable information about web resources or other things (Berners-Lee, 1997).

Traditional physical libraries employ metadata in the library catalogues. In digital libraries, metadata is obtained by cataloguing resources such as books, periodicals, web pages, digital images and DVDs, etc. The data is stored in the integrated system, using MARC metadata standard. The purpose is to direct users to the location of the items and a detailed description of the items. Recently, standards for metadata in the digital libraries include Dublin Core, DDI («Metadata», 2014). Different metadata elements are needed to perform different tasks, for example, author, title and subject support the function of discovery. A DL may require many more forms of metadata than analogue for the management and use. According to the National Information Standard Organization’s (NISO) publication “Understanding Metadata”, there are descriptive metadata, administrative metadata and structural metadata.

A metadata scheme is a collection of metadata elements gathered to support a function, or a series of functions. The collection forms a structured container, to which data values are added and the data values may be uncontrolled or controlled (Greenberg, 2005). A single metadata scheme may be expressed in a number of different markups or programming languages, each of which requires a different syntax. For example, the Dublin Core, which comprises 15 basic metadata elements that are deemed essential for resource discovery, may be expressed in plain text, HTML, XML and RDF.

Cataloguing electronic works digitized from an existing holding may be as simple as copying or moving a record of print to an electronic format, however cataloging complex and created digital works require substantially more effort. To handle the growing volume of electronic publications, new tools and technologies must be designed to allow effective automated semantic classification and search, this is a challenge that DL faces to provide information to users (Fox, 1999; Candela et al., 2011 and «Digital Library», 2014).

2.2.3. Copyright and license

“The advent of digital technology has further altered the concepts and methods of storage and dissemination of data” (Ahmed & Nandekar, 2012).

In the age of digital technology, the need for a more efficient, accurate and reliable tool to facilitate accessibility of works cannot be overemphasized. In this way, several initiatives have

come up with possible ways of facilitating access to knowledge while safeguarding the public interest, one good example is the Project Gutenberg, which works to digitize out-of-copyright works and make them freely available to the public.

The Project Gutenberg is a volunteer effort to digitize, archive and distribute cultural works via book scanning. Founded in 1971, is the oldest DL. Most of the items in its collection are the full texts of public domain books, the releases are available in plain text but, wherever possible, other formats are included, such as HTML, PDF, EPUB, MOBI, and Plucker. With over 45,000 free ebooks, when we can choose among free epub books, free kindle books, download them or read them online. The mission is to encourage the creation and distribution of eBooks. Break down the barriers of ignorance and illiteracy («Project Gutenberg», 2014).

Digital libraries are faced with the issues of license and copyright, since the digital copyright laws are still being formed, unlike the rights of authors of traditional printed works. This fact relates to rights holders who require permission for online publication. There is also a conflict of interests between libraries and publishers wishing to create online versions of their purchased content for commercial purposes. Another issue that complicates matters is the desire of some publishing houses to restrict the use of digit materials such as e-books purchased by libraries. Whereas with printed books, the library owns the book until it can no longer be circulated, publishers want to limit the number of times an e-book can be checked out before the library would need to repurchase that book (Hooper, 2012; Merrill & Raduche, 2013 and «Digital Library», 2014).

The area of copyright and licences are complex and granular, surrounded within a mesh of laws and precedents. Definitions will always be tinted with uncertainty and overlap, and can end up in court for final judgements, because some aspects are not clear and digital copyright laws are still being formed, (U.S. Congress, 1989; Muir, 2003; Hooper, 2012; Ahmed & Nandekar, 2012; Merrill & Raduche, 2013 and «Digital Library», 2014). Also according to Hooper (2012), copyright licensing is expensive, difficult to use, difficult to access, insufficiently transparent. It takes the form of silos within individual media types which are insufficiently international in focus and scope and is victim to a misalignment of incentives between creators, rights owners, rights managers, rights users and end users.

Digital environment provides consumers with the capabilities to be printer/publisher, on a smaller, less-visible scale. This is becoming a very serious challenge, because uses of technology

can exploit persistent ambiguities in existing laws. Copyright is an important issue in intellectual property rights in digital era (U.S. Congress, 1989; Muir, 2003; Hooper, 2012; Ahmed & Nandekar, 2012; Merrill & Raduche, 2013 and «Digital Library», 2014).

However, one of the possible solutions to address the problem in some cases of the copyright is the Creative Commons.

Creative commons is a non governmental and non-profit organization was founded in 2001 by Larry Lessig, Hal Abelson, and Eric Eldred, whose aim is to expand the amount of creative works available through its licenses that allow copying and sharing with fewer restrictions than traditional all rights reserved, to this end, the organization has created several solutions known as Creative Commons licenses.

Creative Commons has been embraced by many content creators because it allows control over how their intellectual property will be shared. Licenses created by the organization allow copyright holders (authors) to abdicate in favor of the public some of their inherent rights to their creations, although others retain those rights. Nevertheless, some criticize the idea accusing it of not being comprehensive enough this issue which can be resolved in the future («Creative Commons», 2014).

2.3. Digital Libraries Reference Model

This sub-chapter will address issues related to the reference model for digital libraries, but first we will address the issue of ontology in the digital libraries fields, to then make a bridge with the reference model showing the importance of this model for DLs, since ontologies are a crucial part in this aspect.

References Models to DLs in particular three models: 5S, OAI (Open Archival Information System) and Delos reference model is mentioned, with special emphasis on the last of the list that is the object in this research. The purpose is to see the references models in the context of digital libraries and what their contributions for create a common model that describe all DLs.

2.3.1. Ontologies in Digital Library

This topic covers the issue of ontology not as a whole, but a brief definition in order to give us a sense of what is the ontology, its history and the fields in which it covers as well as a special highlight of its scope in DL.

2.3.1.1. Ontologies

Nowadays, there are a lot of definitions of the ontology. It mostly depends on the task: how and why ontology is used.

The term ontology has been used for many years, to mean different things like: glossaries and data dictionaries, thesauri and taxonomies, controlled vocabulary, schema and data models, and formal ontologies and inference. And also in many areas (philosophy, artificial intelligence, knowledge-based systems) to organize information. There are found in the literature several definitions of ontologies, several types proposed for application in different areas of knowledge and proposals for building ontologies (methodologies, tools and languages). However, according to Ramalho (2010), in the area of computer science the term ontology was first used in the Mealy work (1967) entitled "Another Look at Data", in a passage in which are presented three distinct realms of area data processing such as:

1. **the real world;**
2. **ideas about what exists in the mind of man;**
3. **the symbols on paper or some other storage medium.**

The philosophical field ontology was not as successful as computer scientists, where they built some large and robust ontologies, such as WordNet and Cyc, with comparatively little debate over how they were built (McGuinness, 2003; Pidcock, 2003; Ramalho, 2010, Sawsaa & Lu, 2014 and «Ontology (information science) », 2014).

Since the 1990s ontology has gained attention in both academic and industrial fields, with the popularity of web pages there was a significant increase in interest for developing ontologies, due to the need to create knowledge bases shareable and reusable, motivating the creation of forums such as the conferences about ontologies. (Smith & Welty, 2001; Ramalho, 2010, «Ontology (information science) », 2014 and Sawsaa & Lu, 2014).

Since then, according Smith & Welty (2001) and Almeida & Bax (2003), ontologies have aroused the interest of many researchers in Computer Science, being able to highlight main areas: Database, Software Engineering, Semantic Web, Information Architecture, knowledge engineering, knowledge representation, qualitative modelling, language engineering,

information retrieval and extraction, and knowledge management and organization and Artificial Intelligence as a form of knowledge representation about the world or some part this, describing:

- **Individuals** (the basic objects);
- **Classes** (sets, collections, or types of objects);
- **Attributes** (properties, features or parameters that objects can have and share);
- **Relationships** (the ways objects can relate to other objects) and
- **Events** (The changing of attributes or relations).

For the Web page classification, ontologies are also applied in classification of emails and news in digital format. Ontologies do not always have the same structure, but there are common features and basic components present in most of them. Even having different properties, it is possible to identify well-defined types such as the five characteristics outlined above and also: **Function terms, Restrictions, Rules** and **Axioms**. (Smith & Welty, 2001; Almeida & Bax, 2003; McGuinness, 2003; Gamage and Wijewickrema, 2013 and «Ontology (information science) », 2014).

On the other hand, Almeida & Bax (2003), Ferran & Minguillón (2005) and Shelt et all (2005) say that, the ontology defines the rules governing the combination of terms and relations. The relationships between the terms are created by experts and users to formulate queries using the concepts specified. Ontology defines a "language" (set of terms) which will be used to formulate queries, thus describing the richness of possible usage scenarios of digital libraries and the relationships that can be established between all participants. Nonetheless, ontologies also include a set of semantic rules which are used to infer knowledge from a structured hierarchy of information, giving to the complete structure a semantic meaning, not only syntactic.

However, according Sawsaa and Lu (2014), there is a lack of domain ontologies in computer-based applications has led to the loss of knowledge in specific domains, but ontologies can be the solution to this problem, promising to give them some kind of sense of meaning about the fact terms. Ontology has the potential to overcome the problem and make the conceptualization of domain Information Science explicit and understandable and also offer a good solution for data use and sharing at syntax level. Ontology is a moulding tool that provides a formal description of concepts and their relations as a foundation for semantic integration and interoperability.

In the DLs fields, ontologies can be used to: organize bibliographic descriptions, represent and expose the contents of the document and share knowledge between users. It's important to note that the use of ontologies in digital libraries allows us to transfer the profile, the user's browsing behaviour to other digital libraries and databases, so that when a user of a particular DL leaves a service to connect to another DL, the user profile (including preferences and navigation behaviour) can be transferred from one base to another by using the appropriate semantic web services because all databases share a common domain of discourse that can be played by rules inference and application logic. For this we have a vast list of ontology languages that allows us to design ontologies according to our needs, however when it comes to design ontology for digital libraries pertinent examples exist such as: RDF (Resource Description Framework), in the family of W3C which is used for describing resources; XML(Extensible Markup Language), for describing data, information and knowledge; OWL(Web Ontology Language), is becoming the standard for describing ontologies and accessing resources through the web; SKOS (Simple Knowledge Organization System), recommended by the W3C, enable easy publication and use of such vocabularies as linked data; etc. (Ferran & Minguillón, 2005; Castro et al., 2010 and «Ontology (information science)», 2014).

Following from the above discussion it is clear that ontologies enable the development of new kinds of information and significant improvements in the processes of representation, organization and retrieval of information and knowledge in digital environments, with very innovative perspective services for digital libraries such as: automatically provide contextualized results through the integration of information, the development of automatic methods, or semi-automatic, document selection; linguistic and semantic compatibility, from the realization of automatic inferences. Summarizing, ontologies represent a potential for the digital libraries fields. Ramalho (2010) adds that from the use of ontologies, information professionals see multiply the possibilities of professional performance through incorporation of new capabilities to the processes of representation, organization, dissemination and retrieval of information.

2.3.2. References model for Digital Library

The dynamics of services around DLs has over the years attracted several models and theories of DLs proposed to serve as a framework for building digital libraries that will meet the information needs of users in the new global environment (Isah et al., 2013).

DLs need a reference model that corresponds to the consolidation of a diversity of approaches throughout a cohesive and consistent whole to provide a mechanism that allows the comparison of different systems of DL, to provide a common basis for communication within the DL community, and help focus further advancement (Candela et al., 2007; Athanasopoulos et al., 2010; Candela et al., 2011 and Isah et al., 2013)

A reference model is an abstract framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment. It is based on a minimum of unifying concepts, not directly (independent) tied to any standards, technologies or other concrete implementation details, but it does seek to provide a common semantics that can be used unambiguously across and between different implementations (Casarosa, 2010 and «Reference model», 2013).

Reference models have a number of important concepts according to («Reference model», 2014; «Digital library», 2014):

- **Abstract** - reference model describes the type or kind of entities that may occur in such an environment, not the particular entities that actually do occur in a specific environment;
- **Entities and relationships** - describes both types of entities (things that exist) and their relationships (how they connect, interact with one another and exhibit joint properties). A list of entity types, by itself, doesn't provide enough information to serve as a reference model;
- **Within an environment** - should include a clear description of the problem that it solves, and the concerns of the stakeholders who need to see the problem get solved;
- **Technology agnostic** - typically is intended to promote understanding a class of problems, not specific solutions for those problems («Reference model», 2014; «Digital library», 2014).

Due to the inherently interdisciplinary nature of digital libraries they must integrate findings from disciplines such as hypertext, information retrieval, multimedia services, database management, and human-computer interaction, the understanding of the underlying concepts and functionalities of digital libraries, thus makes it difficult and expensive to construct new DL systems. The broad and deep requirements of digital libraries demand new frameworks and

theories in order to understand better the complex interactions among their components (Gonçalves, 2004).

Formal models and theories are crucial in order to specify and understand clearly and unambiguously the characteristics, structure, and behaviour of complex information systems. In line with this assertion, different practical and research efforts towards models and theories of digital libraries have been developed (Gonçalves, 2004).

According to Isah et al. (2013), the Digital Library Initiative (DLI) projects in the US and the eLib projects in UK have been the major drivers of these efforts through research and practical projects. There are now a number of models of digital libraries that can serve as a framework for best practices. Some of these models are based on DELOS Digital Library Reference Model or Streams, Structures, Spaces, Scenarios, Societies (5S) formal framework or Reference Model for an Open Archival Information System (OAIS) are defined by proposing a formal ontology that defines the fundamental concepts, relationships, and axiomatic rules that govern the DL domain, defining a quality model for DLs. And each of them will be described in the following subchapters.

2.3.2.1. (5S) Formal framework

A quality model for digital libraries was elaborated in 2007 within the 5S (streams, structures, spaces, scenarios, and societies) theoretical framework, the model was addressed to DL managers, designers and system developers, and defined a number of dimensions and metrics which were illustrated with real case studies (Vullo, 2010 and Isah et al., 2013).

The 5S framework allows defining digital libraries rigorously and usefully, as a framework for providing theoretical and practical unification of digital libraries. This framework was proposed as a formal theory for describing digital libraries. It captures the complexity of the Digital Libraries, as shown in Figure 1. Digital Libraries can be described using the 5S's (Kelapure et al, 2004; Gonçalves, 2004; Gonçalves & Fox, 2005; Shen, et al 2006; Murthy et al, 2007; Kozievitch, 2009 and «The Digital Libraries Reference Model», 2014).

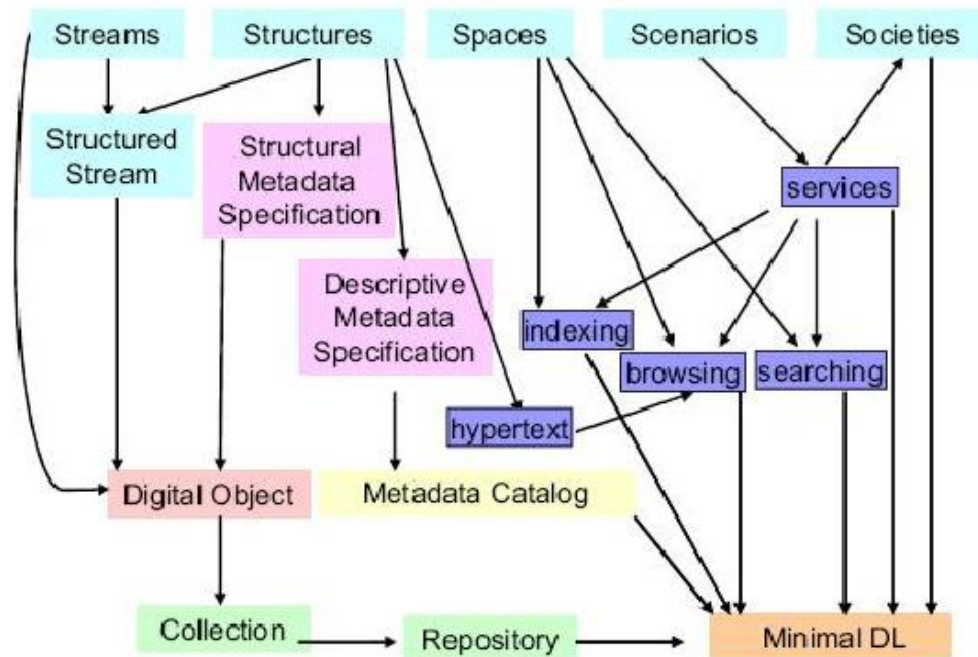


Figure 1 - 5S Definition structure

Source: Gonçalves et al (2004)

1. Streams

Streams are sequences of elements of an arbitrary type (eg. bits, characters, images, video, audio) and these can model both static and dynamic content. The static streams represent the information content as basic elements and complex elements. For example: for textual material, simple text is a string that represents basic elements and a complex object may be a stream of text and simple graphics or presentation of a digital video. Streams are used for dynamic model any flow of information, either basic or complex and these are used to represent any communication that occurs in the DL. Streams are typed and the type is used to define their semantics and application area (Gonçalves, 2004; Gonçalves & Fox, 2005; Kozievitch, 2009, Isah et al., 2013 and «The Digital Libraries Reference Model», 2014).

2. Structures

Structures specifies the way through which parts of a whole are organized, they can be used to represent hypertext and structured information objects, taxonomies, system connections, user relationships and containment, to cite a few, e.g., structured streams such as metadata specifications and digital objects. (Gonçalves, 2004; Kelapure et al., 2004 ; Kozievitch, 2009, Isah et al., 2013 and «The Digital Libraries Reference Model», 2014).

3. Spaces

A space is a set of objects together with operations on those objects that obey certain constraints, define logical and presentational views of several DL components,. Is a powerful construct, when a part of a DL cannot be described well using another of the 5Ss, a space may well be applicable, document spaces are the key concepts in digital libraries. Spaces are used in different contexts (e.g. indexing and visualising) and types (measurable spaces, measure spaces, probability spaces, vector spaces and topological spaces) (Murthy et al., 2007; Kozievitch, 2009, Isah et al., 2013 and «The Digital Libraries Reference Model», 2014).

4. Scenarios

Scenarios are sequence of events that also can have a number of parameters. Parameters represent specific variables defining a state and their respective values and events represent state transitions. The state is determined by the content in a specific location. Scenarios can be used to describe external system behaviour from the users point of view; provide guidelines to build a cost-effective prototype; or help to validate, infer, and support requirements specifications and provide acceptance criteria for testing. Thus a scenario tells what happens to the streams in spaces and through the structures (Murthy et al., 2007; Kozievitch, 2009, Isah et al., 2013 and «The Digital Libraries Reference Model», 2014).

5. Societies

A society is a set of entities and the relationships between them, and can include both human users of a system as well as automatic software and hardware, which use or support DL services, they exist to serve the information needs of its societies and to describe the context of its use (Murthy et al., 2007; Kozievitch, 2009, Isah et al., 2013 and «The Digital Libraries Reference Model», 2014).

A quality model for digital libraries was elaborated in 2007 within the 5S (theoretical framework), the model was addressed to DL managers, designers and system developers, and defined a number of dimensions and metrics which were illustrated with real case studies. These 5Ss, along with fundamental set theoretic definitions, are used to define other DL constructs such as digital objects, metadata specification, collection, repository, and services (Murthy et al, 2007 and Vullo, 2010).

In DL the 5S are related to:

- Streams concern the communication and consumption of information by users.
- Structures support the organisation of the information in usable and meaningful ways.
- Spaces deal with the presentation and access to information in usable and effective ways.
- Scenarios provide support for the definition and design of different kinds of services.
- Societies define how a DL helps in satisfying the information needs of its users («The Digital Libraries Reference Model», 2014).

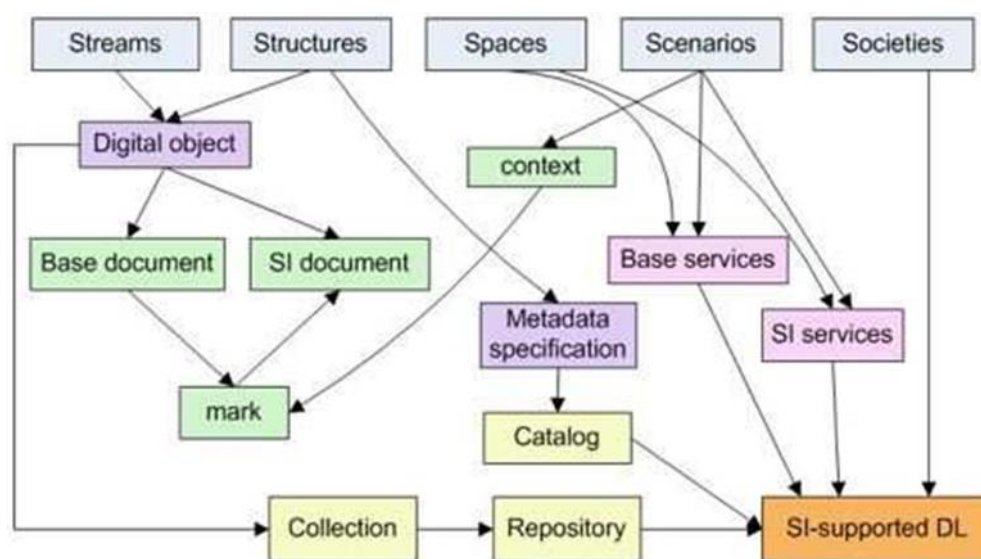


Figure 2 Example of 5S supported DL

Source: Gonçalves et al (2004)

2.3.2.2. Open Archival Information System (OAIS).

Open Archival Information System (or OASIS) is an archive system dedicated to preserving and maintaining access to digital information over the long term, and make it available for a specific community. The Reference Model was designed as a conceptual framework in which to discuss and compare archives. Defined by CCSDS (Consultative Committee for Space Data Systems) with the purpose of the reference model is to increase awareness and understanding of concepts relevant for archiving digital objects, especially among monarchical institutions; elucidate terminology and concepts for describing and comparing data models and archival architectures, nevertheless the CCSDS is a space agencies, the OAIS model it developed has proved useful to

a wide variety of other organisations and institutions with digital archiving needs (*Lavoie, 2000*; CCSDS, 2002; CCSDS, 2012; «Open Archival Information System», 2014).

According to CCSDS (2002), CCSDS (2012) and «Open Archival Information System» (2014) the reference model should:

- Provide a framework for the understanding and increased awareness of archival concepts needed for long term digital information preservation and access them, as well as expand consensus and promote a larger market which vendors can support;
- Provide the concepts needed by non-archival organisations to be effective participants in the preservation process;
- Provide a framework, including terminology and concepts, for describing and comparing architectures and operations of existing and future archives and provide a framework for describing and comparing different long term preservation strategies and techniques;
- Provide a basis for comparing the data models of digital information preserved by archives and for discussing how data models and the underlying information may change over time;
- Provide a foundation that may be expanded by other efforts to cover long-term preservation of information that is not in digital form, but in physical form also; and
- Guide the identification and production of OAIS-related standards.

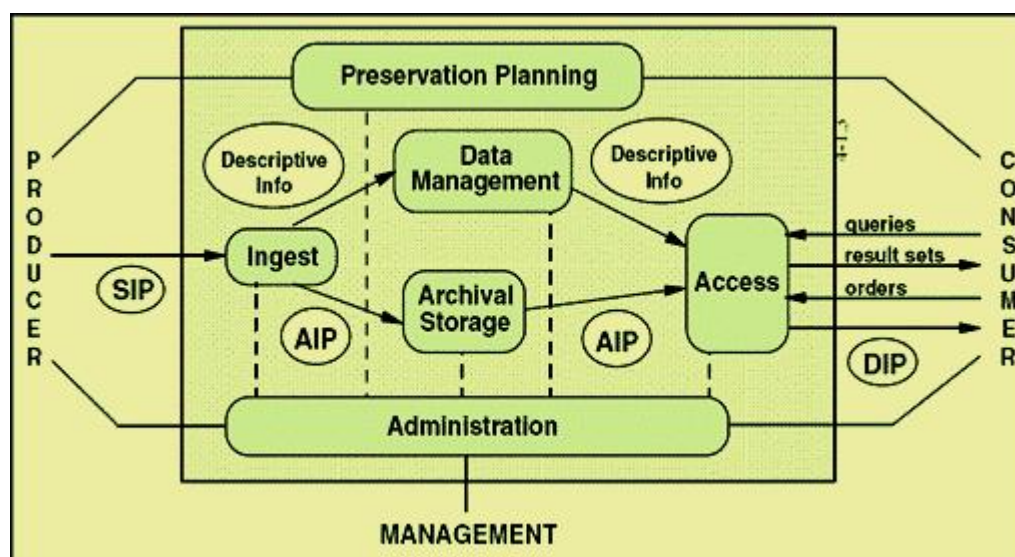


Figure 3 - OAIS Functional Entities

Source («Open Archival Information System» (2014))

2.3.2.3. DELOS - Digital Library Reference Model

DELOS is a Network of Excellence on Digital Libraries partially funded by the European Commission in the frame of the Information Society Technologies Programme. The DELOS vision for digital libraries is the same as the purpose of the DL, is that they should enable any citizen to access all human knowledge anytime and anywhere, in a friendly, multi-modal, efficient and effective way, by overcoming barriers of distance, language, and culture and by using multiple Internet-connected devices. The DELOS project aims at integrating and coordinating the ongoing research activities of the major European teams working in DL-related areas with the goal of developing the next generation DL technologies (Casarosa, 2007).

However they want more, that new generation digital libraries should not just be seen as static information repositories but as growing, interactively, and collaboratively used nuclei of what will be at some stage, a good part of human knowledge that depends as much on information as on communication.

With this, the mainly two aims are:

- To contribute to the development of enabling technologies so that their vision for digital libraries may become reality;
- Disseminating knowledge of DL technologies to many diverse application domains;

Therefore, it can provide specific user communities with access to advanced DL technologies, services, test beds, and the necessary expertise and knowledge to facilitate their take-up. So, activities fall into three major categories: research, integration and dissemination (Delos, 2013 and Athanasopoulos et al., 2010).

The DLRM resulted from consolidation and enhancement activities performed in the framework of the DL.org project. It introduces the principles governing such a model as well as the set of concepts and relationships that collectively capture the intrinsic nature of the various entities of the DL universe (Candela et al., 2011).

The reference model activity, begun in October 2004 by a core group of DELOS members, will soon be taken up by other DELOS groups, working from the perspectives of different domains. Connections with similar activities carried out by other research groups and initiatives at international level will be established in order to achieve a global and stable level of consensus

on the model. It is difficult to establish a consensus because, they concern several different areas, which makes it difficult to compare or combine the results achieved in these areas since it is not always clear how they are related, and how they can impact on or constrain one another (Athanasopoulos et al. 2010).

Despite the large number of software tools named “digital library systems”, there is no agreement yet on what Digital Libraries and Digital Library Management Systems (DLMSs) are and on which functionality they must provide. Existing systems are heterogeneous in scope and focus on very different aspects and functionality. These systems range from digital objects/metadata repositories, reference linking systems, archives and commercial systems that provide administration functions, to complex systems (mainly developed in research environments) that integrate advanced DL services.

Reflecting the structure of the DL universe the DLRM is segregated into six (6) sub-domains comprising interrelated concepts and terms i.e. the **Content, User, Functionality, Quality, Policy** and **Architecture domains**. Concepts from each of these sub-domains are materialized in nearly every existing DL and these concepts will be described further below (Candela et al, 2011).

The RM fundamentals at three-tier Framework, that have an important role in the DL development process, with their individual characteristics, according to Athanasopoulos et al. (2010); Casarosa, 2010; Candela (2011) and («The Digital Libraries Reference Model» (2014):

- **Digital Library (DL)**

DL is a virtual organisation, which comprehensively collects, manages and preserves rich digital content for the long term, and offers to its user communities specialised functionality on that content, of defined quality and according to comprehensive codified policies;

- **Digital Library System (DLS)**

Whereas, DL system is a software system that is based on a defined architecture that provide all functionality required by a particular DL. Users interact with a DL through the corresponding DLS.

- **Digital Library Management System (DLMS)**

For her turn, DLMS is a generic software system that provides the appropriate software infrastructure both, to produce and administer a DLS incorporating the suite of functionality considered fundamental for DL as to integrate additional software offering more refined, specialised or advanced functionality. So, manage all the DLS as we can see in the figure 4.

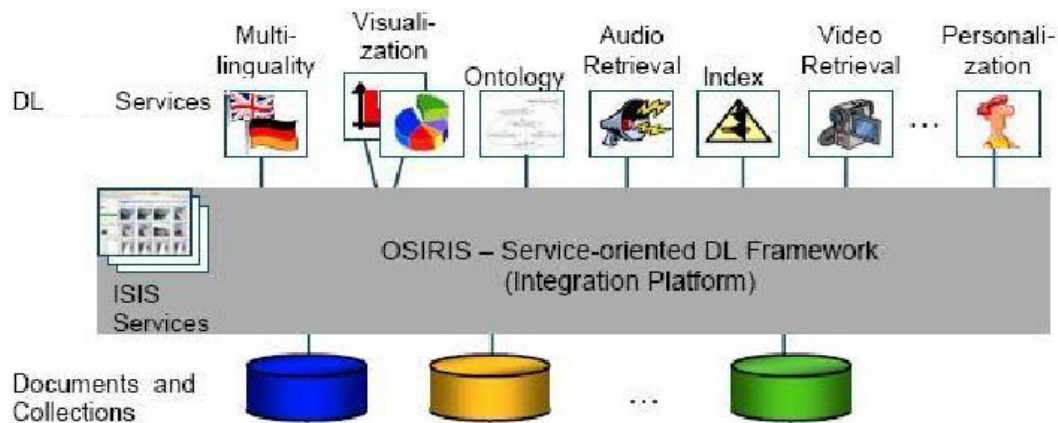


Figure 4 - Delos Digital Library Model

Source (Casarosa, 2010)

Even if, the concept around of DL is intended to capture an abstract system consisting of both physical and virtual components, the DLS and the DLMS capture real software systems (Athanasopoulos et al., 2010). These correspond to three different levels of conceptualisation of the universe of DL like show the figure 5.

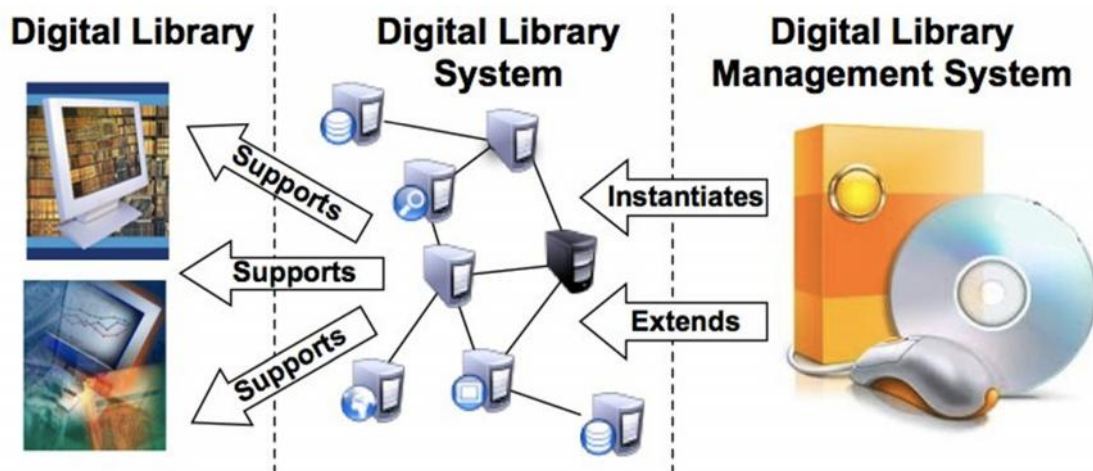


Figure 5 – A three-tier Framework (DL, DLS and DLMS)

Source (Candela et al., 2010)

The same authors mentioned above and Isah et al. (2013), still defined the constituent domains that is Digital Library Domain (DLD) have all the elements needed to represent the three systems of the DL universe, and can be divide in two classes:

- ***DL Resource Domain*** - contains elements identified as ‘first class citizens’ in modelling the DL universe and have a small number of fundamental concepts and they are identifiable in nearly every DL currently in use, classify by:
 - **Content** - represents the information managed and makes available to its users;
 - **Functionality** – is the services that a DL offers to its different users;
 - **User** - represents the actors, entity interacting with the system (Digital Libraries);
 - **Quality** - represents the parameters that can be used to characterise and evaluate the content and behaviour of a DL from a quality point of view;
 - **Policy** - represents the conditions, rules, terms and regulations governing interaction between the DL and users, whether virtual or real; and
 - **Architecture** - represent the DLS entity and represents a mapping of the functionality and content offered by a DL on to hardware and software components.

Complementary Domain - includes concepts such as:

- **Time domain** - concepts and relations needed to capture aspects of the time sphere such as time periods and intervals;
- **Space domain** - concepts and relations needed to capture aspects of the physical sphere such as regions or locations; and
- **Language domain** - concepts and relations needed to capture aspects of the method of communication, either spoken or written, consisting of the use of words in a structured and conventional way.

Although they do not constitute the focus of the DL and can be inherited from existing models, are nevertheless needed to represent the systems, the figure 6, show the main concept in the DL

universe, these concepts share many similar characteristics and they all refer to internal entities of a DL that can be discerned in the outside world (Athanasopoulos et al., 2010; Candela, 2011; Isah et al., 2013 and «The Digital Libraries Reference Model», 2014).

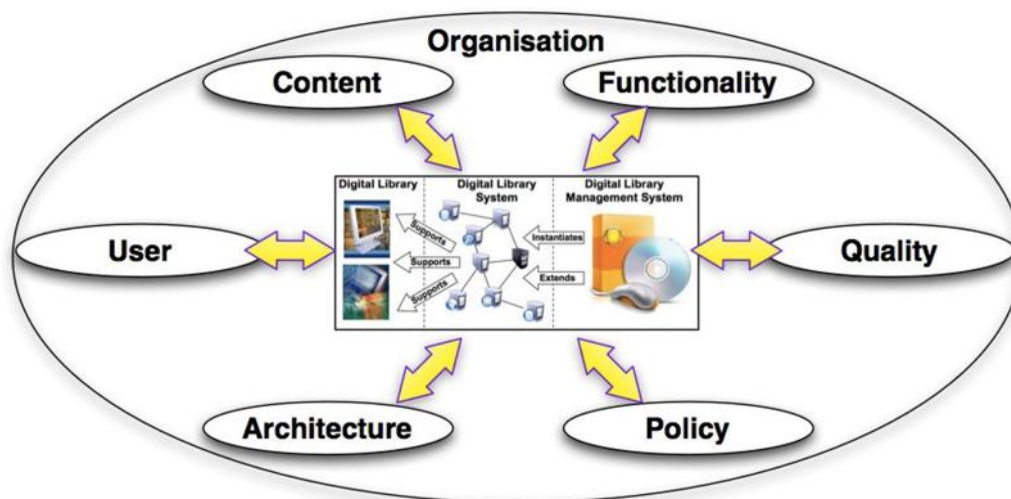


Figure 6 - Main concept in the DL universe

Source (Candela et al., 2011)

Among these six concepts, the other two are independent, since they are independent of a DL. The user that is external humans or hardware that interacts with the Digital Content Library and which represents the material handled by the DL. In turn, the architecture, which is the technology that underpins the project of the DLS, is the underlying technology that implements all the rest.

Functionality, which mainly represents the means to connect users to the content is not considered because they are all procedures, transformations, actions and interactions that bring content to the user and vice versa. Finally, the operation of the DL and activation of its functionality are based on policy and seek to achieve a certain level of quality (Athanasopoulos et al., 2010 and Candela et al. 2011).

It is also important to emphasize here that the players acting in the DL universe, are:

- The **DL End-Users** are the ultimate clients the DL is going to serve;
- The **DL Designers** are the organisers and orchestrators of the DL from the application point of view;
- The **DL System Administrators** are the organisers and orchestrators from the physical point of view; and

- The **DL Application Developers** are the implementers of the software parts needed to realise the DL (Candela et al. 2011 and «The Digital Libraries Reference Model», 2014).

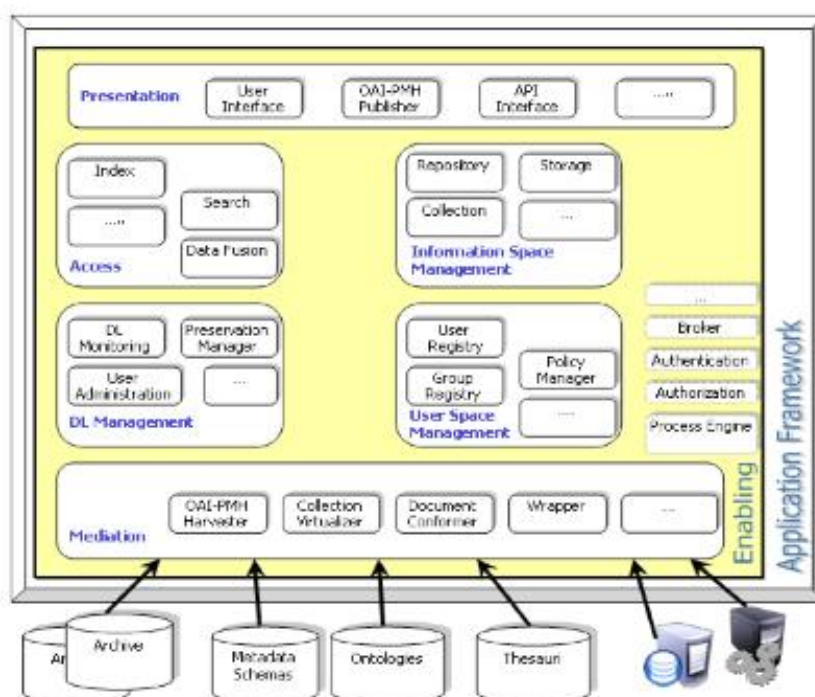


Figure 7 – Delos References Model

Source: (Casarosa, 2010)

2.3.3. Comparison between Delos References Model and 5s

Isah, et al. (2013), in his research entitled "Digital Libraries: Analysis of Delos Reference Model and 5S Theory" and supported by authors such as Fox et al. (2003), Gonçalves (2004) Innocenti, et al. (2011) and Candela et al. (2011) did a comparison of these two models where he noted that:

Innocenti, et al. (2011) say that, the DELOS Reference Model is intended as a roadmap to enable the wider DL community to follow the same route and share a common understanding when dealing with the entities of the DL universe;

On the other hand, Gonçalves (2004) says that the 5S framework is built on this premise to provide a foundation for the definition of the DL toward achieving theoretical and practical unification, Gonçalves (2004) identify the 'minimal digital library'. So we can conclude that these two models have common purpose or objective is to provide a standard framework for DL

projects, but the methods employed in the presentation of DL frameworks are quite different, though their concepts still address the core components of DLs.

While the 5S framework applies a rigorous definition of various concepts for DLs, DELOS reference model focuses on identifying the key concepts and relationships encompassing the entire the DL.

5S framework define DL individual aspects in terms of abstract entities, and these five levels (streams, structures, spaces, scenarios, and societies) of abstraction and their associated formalisms also render it difficult to adopt due to the complexities involved. Nevertheless, DELOS Reference Model defines six (6) main domains (content, user, functionality, quality, policy, and architecture), which are explicit and serve as a foundation for assessment of DLs, but the organization of three distinct systems (Digital Library, Digital Library System, and Digital Library Management System) into one framework makes the DELOS model complex in nature, even Fox et al. (2003) add, Delos references model have a lacks strong emphasis on social aspects of digital libraries compared to 5S Theory .

Although there are some areas covered in the DELOS Reference Model's, six main domains which are not distinctly represented in the 5S main constructs, this refers to policy and quality domains. 5S Theory provides a separate quality model which makes up for quality constructs not explicitly covered in the main 5S (Candela et al., 2011). The figure 8 show a correspondence between the area covered by the 5S framework and the Reference Model, 5S basically covers what in the Reference Model have been called Content, Functionality and User main concepts, like we say before. DLRM does have potential as a description profile for digital libraries (Ohren, 2009).

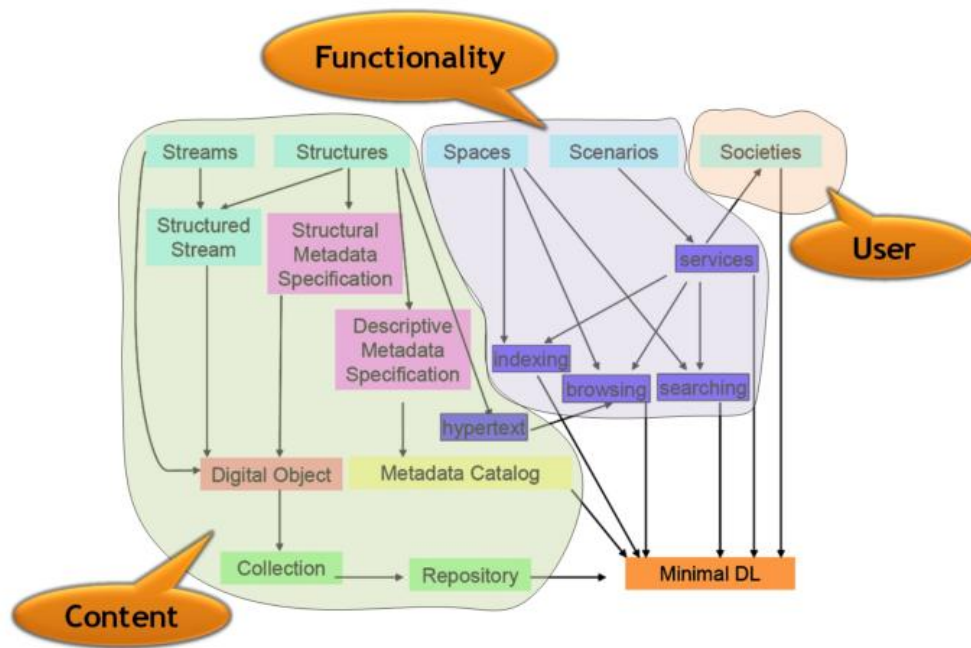


Figure 8 - 5S framework and Delos References Model
 Source: Gonçalves (2004) & Candela et al., 2011

Regarding the relationship they have a common relationships are in such areas as Streams, Contents, Societies, and Users constructs. These two related concepts address the same component of a DL. The commonality of the two concepts can be vividly identified when applied to different DLs.

The DELOS Reference Model Theory and 5S are the two attempts which highlight a single model representing several digital libraries.

Chapter 3 Methodology of reserach

This chapter discusses the research methodology of this thesis and provides justification for the choices made regarding the research method and methodology most appropriate to build an ontology. This section of the chapter will also look at the reasons why the method and methodology fit the purpose of the investigation, namely how they fulfill the research objectives and how they can provide answers to the research question.

The methodology chapter is divided into several subchapters which will examine the process of planning, developing and delivering case study method as a chosen. Firstly we will focus on the theoretical basis, giving a brief definition about the methodology being used for this research, namely a qualitative exploratory methodology and also a case study method. Then the focus will be Methontology, a method inside the case study chosen to develop the ontology. In the following subchapter the focus will be switched to Ontology life cycle where will be describe each step of the lifecycle of the ontology process of development. Finally, the methodology chapter will delineate the step-by-step process of creating the Delos Reference Model ontology following the process of ontology life cycle (specification, conceptualization, Formalization, implementation, maintenance and evaluation), as well the methodology and the method chosen for such a process, the reasons for choosing the case study as a method and methontology as a methodology for this research, to finish the description of each step of ontology life cycle of this research.

3.1. Introduction

Methodologies here propose methods for carrying out the ontology. In order to try to give an answer to the research question stated above, it is necessary to build the Delos Reference Model ontology. Methodologies, generally set out guidelines specifying how you should carry out the activities identified in the development of ontologies, what kinds are the most appropriate techniques for each activity and what products each producing process (Fernandez et al., 1997). The Method is chosen according to the research aims and the need to answer the research question. The first step of this approach is to analyse the Delos references Model and construct a web ontology that captures the domain knowledge.

Basically, a series of approaches have been reported for developing ontologies. The nature of the ontology is a concept model. The concept model represents the relationship of concepts within the domain, and it is also considered a model of a domain since it combines the characteristics of domain **Concepts**: set of entities in a domain. **Relationships**: interactions between domain concepts. **Axioms**: explicit to limit the use of concepts rules. **Instances**: concrete examples of concepts in the field (Zhang, 2008 and Sawsaa & Lu, 2014).

To create Delos Reference Model ontology follows Methontology based on IEEE standard criteria to design an ontology life cycle process.

3.1. Theoretical Bases

In the sub-chapter theoretical basis some theoretical issues will be covered related to methodologies like the concept and the applicability of: qualitative methodology, exploratory research, case study method and the IEEE standard in order to better understand the methodology used in this research.

3.1.1. Qualitative methodology

Qualitative approaches are characterised by a focus on description, interpretation and evaluation of the social world and typically adopt a holistic approach to a research problem. Unlike quantitative research, which seeks to create generalizable results from numerical data, qualitative studies investigate complex social environments and aim to develop new insights, concepts or theoretical perspectives relating to that particular phenomenon. This is opposed to the assumption that advocates a single research model for all sciences since each has its own characteristics,

which presupposes a methodology itself. (Kohlbacher, 2006; Neville, 2007; Lewis, 2008; Creswell, 2008 and Gerhardt & Silveira, 2009). Qualitative approaches to research is more subjective in nature than quantitative research and involves examining and reflecting on the less tangible aspects of a research subject, e.g. values, attitudes, perceptions (Neville, 2007 and Lewis, 2008).

3.1.2. Exploratory Research

Exploratory research is defined as the initial search in a hypothetical or theoretical idea. It is a survey conducted by a problem that was not clearly defined, in some cases occur before we know enough to make conceptual distinctions or postulate an explanatory relation. It helps determine the best research design, the data collection method and selection of subjects and definitive conclusions only with extreme caution. Exploratory research is a secondary, or complementary research, in order to gain familiarity with a phenomenon or gain a new perspective on it, in order to formulate a more precise problem or develop a hypothesis, exploratory studies, although the results of exploratory research generally are not useful for making decisions for themselves, but they can provide significant insight into a given situation. The vast majority of this research involves: literature survey, interviews with people who have had practical experience with the problem studied, analysis of examples that encourage understanding. An exploratory research project is an attempt to lay the foundation that will lead to future studies, or to determine if what is being observed can be explained by a currently existing theory. (Neville, 2007; Gerhardt & Silveira, 2009 and « Exploratory research », 2014)

3.1.3. Case Study

“A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 2009).

The case study is a research strategy in which the researcher explores in depth a program, event, activity, process, one organization, individual or a group of people, and usually involves gathering and analysing information; information that may be both qualitative and quantitative. The case study method allows researchers to obtain the holistic and meaningful characteristics of real life events, seem, according Kohlbacher, (2006) to be the preferred strategy when "how"

and "whys" are used. The cases are limited by time and activity (Neville, 2007; Creswell, 2008 and Farquhar, 2009).

According to Yin (2009) the main steps in undertaking case studies are:

1. **Collecting evidence** - there are six possible sources of evidence: documents (memos, newspaper clippings, etc), archival records (service records, surveys they've conducted), interviews (tape records), direct observation (watch and note), and participant-observation (), and physical artefacts. The case study benefits are followed by the use of multiple sources of evidence, creation of a case study database, maintaining a chain of evidence;
2. **Analyzing case study evidence** - consists of examining, categorizing, tabulating, testing, or otherwise recombining both quantitative and qualitative evidence to address the initial propositions of a study, with the ultimate goal of discovering patterns, determine meanings, construct conclusions and building a theory. This in turn goes through the process: Relying on theoretical propositions; Thinking about rival explanations; Developing a case description (Kohlbacher, 2006);
3. **Reporting case studies** - is the final stage of the case study that is both a process of inquiry about the case and the product of that inquiry, namely the report. The results and findings of a case study must be brought to closure.

With this, case study can achieve: 1 - The phenomena can be studied in their natural environment and meaningful, relevant a theory can be generated from insights gained through actual practice; 2 - the case study method allows the questions of "how" and "why" to be answered with a relatively complete understanding of the nature and complexity (Farquhar, 2009).

3.1.4. IEEE Standard 1074-2006

The IEEE 1074-2006 is a standard for developing a software project life cycle process. It describes the process of software development, the activities to be performed, and the techniques that can be used for software development. The life cycle flow includes 5 phases: Specification, Conceptualization, Formalization, Implementation and Maintenance, which will be explained in each phase in the chapter about life cycle ontologies. These activities do not have a time order, since the standard recommends that they be incorporated into a software life

cycle which is selected and set by the user for the project development. The activities are part of what is called software process, which is further divided into four main processes:

1. Software life cycle model process - includes the activities of identifying and selecting a software life cycle, which establishes the order in which the different activities involved in the process should be performed;
2. Project management processes - create the framework for the project and ensure the appropriate level of management of the entire lifecycle of the product;
3. Software development-oriented processes - produce, install, operate and maintain the software and retire it from use. That include: 1- Pre-development processes; 2 - Development processes, consequently included: 2.1 - Requirements process; 2.2 - Design process; 2.3 - Implementation process; 3 - Post-development processes; and 4 - Post-development processes;
4. Integral processes - are required to complete successfully the activities of software projects. They ensure the completion and quality of project roles. (López, 1999; Yun et al., 2013 and Sawsaa & Lu, 2014).

3.2. Justify the research methodology chosen

In consideration of the definitions of qualitative methodology and quantitative methodology mentioned above, the qualitative methodology is chosen for this research. One of the chief reasons for conducting qualitative study is that the study is exploratory, this usually means according to Creswell (2008), and that not much has been written about the topic or the population being studied. This research is not total exploratory, because the Delos Model References exist but the Delos references Model Ontology still is not built and this constitute the aim of this research.

Taking into account the aim of the research, developing an ontology for the Delos References Model, justifies the technical approach used, since we will not be following the case study research guide, such as the definition of the sample, data collection and management techniques, etc., but the approach will use a methodology that allows the development of ontologies based on the IEEE standard, it will be the methontology.

Also, in this research the case study approach is the chosen method to develop the Delos References Model ontology and the sources of evidence consist of documents (articles, scientific

publications, books and book chapters and sites on the web like Wikipedia). Analysis of the case study evidence follows the literature review, examining, categorizing and testing what exists in related the research field in question and still develop a description of the case study. For this study, case study method can answer how Delos Reference Model can represent several digital libraries, with a relatively complete understanding of the nature and complexity.

Methontology is the methodology chosen to develop the case study, because it uses an iterative approach which allows us to refine the ontology to create the Delos References Model. Ontology method is constructed as follows, using the Delos reference model to create ontology and answer the question: Delos reference model can represent several Digital Libraries? Also so many authors like Fernández et al. (1997); López, (1999); Corcho (2003); González (2005) Yun et al. (2013) and Sawsaa & Lu (2014), recommend that for developing ontologies Methontology is suitable methodology, because ontologies are part of software products, therefore, ontologies should be developed according to the standards proposed for software generally, which should be adapted to the special characteristics of ontologies. Methontology results in the general discourse of this research it has been used in a more narrative and less knowledge engineering oriented way.

3.3. Methontology

Methontology is among the most comprehensive methodologies of ontology engineering, was developed within the Ontological Engineering group at Universidad *Politécnica* de Madrid; it is for building ontologies either from scratch or by reusing other ontologies, or by a process of re-engineering them; the structure enables the construction of ontologies at the knowledge level. The framework is to identify the process of ontology development with the identification of the main activities, identified by the IEEE software development process: Evaluation, Configuration, Management, Conceptualization, Implementation and Integration. Its own methodology specifies the steps for carrying out the activities, the techniques used, the results and their evaluation. (Fernández et al., 1997, Corcho et al.; 2002 and Saws & Lu, 2014).

This particular methodology is used for ontology construction by applying iterative approach. It allows refines the ontology with the purpose of creating more accurate model of the DLD, for this the Methontology is chosen as the methodology to develop the Delos References Model ontology.

The Methontology framework enables the construction of ontologies at the knowledge level. It includes: the identification of the ontology development process, a life cycle based on evolving prototypes as we see in the figure 9. Each cycle moves along the development activities that we can see in the figure 9, although not necessary to go through all of them as it is in this case. The paragraphs below correspond to the research in question and are self-explanatory.

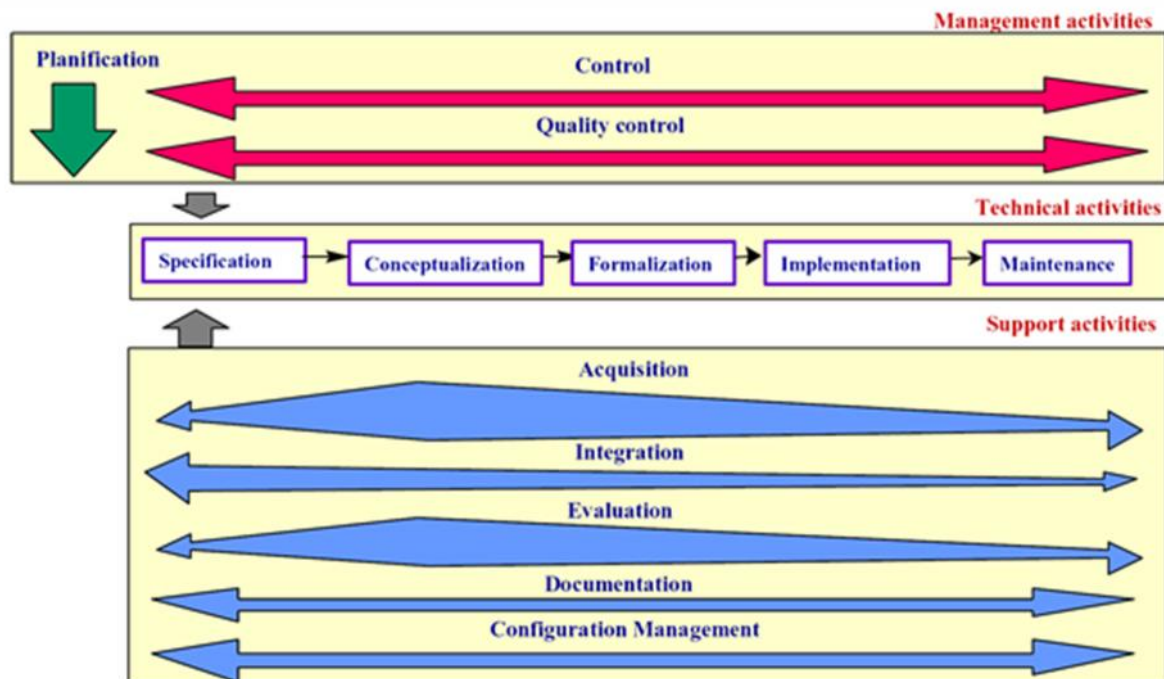


Figure 9 - Methontology ontology development process life cycle

Source: Corcho et al.(2002)

3.4. Ontology life cycle

Ontologies have become a critical component of many applications in so many areas, especially in Information Science and Digital libraries fields, so the landscape of ontology tools today is very fragmented, with independent tools for editing ontologies, publication and peer review, however to develop ontologies consistent and cohesive it is necessary follow some steps proposed by IEEE-1074-2006, that streamlines the workflow for collaborative development and enhances the integration between their own ontologies, these stages through which the ontology moves during its life time, describes what activities are to be performed in each stage and how the stages are related and each phase will match up with the process development of ontology in this research.

3.4.1. Specification

The purpose is elaborating a document, containing information such as according to Fernández et al. (1997); Noy & McGuinness (2001); Corcho et al. (2002) and González (2005):

- Purpose or goals of the ontology - Sharing common understanding of the structure of information among people or software agents;
- Level of formality - depending on the formality that will be used to codify the terms and their meaning and that can be:
 - Highly informal – expressed in natural language;
 - Semi-informal - expressed in structured form of natural language;
 - Semi-formal – expressed in a formally defined language;
 - Formal – define all terms formally;
- Usage scenarios and scope - which includes the set of terms to be represented, its characteristics and granularity;
- Intended uses and end-users - for which purpose and user.

The specification can be informal, in natural language, or formal, e.g. using a set of competence questions or a middle-out approach (Fernández et al., 1997, Corcho et al., 2002 and González, 2005).

The figure below shows a part of the specification document of the research in question. For more detail specification document in the D3.2b The Digital Library Reference Model² can be consulted.

2

Access in <https://www.coar-repositories.org/files/D3-2b-Digital-Library-Reference-Model.pdf>

Documentation of Specification

Domain: Digital Library

Date: August 15, 2014

Developed by: Emília Monteiro Tavares

Purpose: Ontology about Delos Reference Model in order to represent the largest possible numbers of digital libraries.

Level or formality: Semi-formal

Scope: list of: Digital library, Digital Library System, Digital Library System Management

List of the concepts: Organization, Users, Functionalities, Quality, Policies, Architecture....

Sources of knowledge

- a) L. Candela, G. Athanasopoulos, D. Castelli, K. El Raheb, P. Innocenti, Y. Ioannidis, A. Katifori, A. Nika, G. Vullo, S. Ross C. Thanos (2011). D3.2b The Digital Library Reference Model. Access in <https://www.coar-repositories.org/files/D3-2b-Digital-Library-Reference-Model.pdf>
- b) Candela, L.; Castelli, D. and Pagano, P. (2009). On-demand Virtual Research Environments and the Changing Roles of Librarians. From http://www.d4science.eu/files/docs/lht27/lht_preprints.pdf access
- c) G. Athanasopoulos, L. Candela, D. Castelli, P. Innocenti, Y. Ioannidis, A. Katifori, A. Nika, G. Vullo, S. Ross, (2010) The Digital Library Reference Model version 1.0, DL.org: Coordination Action on Digital Library Interoperability, Best Practices and Modelling Foundationsl. From <http://bscw.research-infrastructures.eu/pub/bscw.cgi/d222816/D3.2b%20Digital%20Library%20Reference%20Model.pdf>.

Figure 10 - Ontology requirements specification in the Delos References Model domain.

Based on: Fernández et al., 1997

The purpose of the ontology in this research is building ontology about Delos reference Model in order to represent as many as possible DLs, where the scope is list of super concepts: DL, DLS and DLMS and also mains concepts: content, users, functionality, quality, policy, architecture and so on. The techniques used in the knowledge acquisition phase of the Delos References Model ontology were: Informal text analysis, where we study the main concepts given in books and handbooks. This study enables us to fill in the set of intermediate representations of the conceptualization; Formal text analysis, to identify the structures to be detected (definition, affirmation, etc.) and the kind of knowledge contributed by each one of concepts, attributes, values, and relationships

3.4.2. Conceptualization

The objective of this activity is to organize and structure the knowledge acquired during the acquisition of knowledge using external representations that are independent of knowledge

representation and implementation paradigms in which the ontology will be formalized and executed thereafter. It is necessary to build a complete Glossary of Terms (terms are classified into one or more taxonomies of concepts), it include concepts, instances, verbs and properties, etc. (Fernández et al., 1997, Corcho et al., 2002 and González, 2005). It is the main phase of the methodology this phase organizes and converts a vision of domain informally realized in a semi-formal specification.

In order to have a consistent and complete conceptual model, the activity of conceptualization defines a set of tasks (as shown in Figure 11 below) that must be performed in succession. These tasks increase step by step in complex representations of the intermediates used to construct the conceptual model (González, 2005).

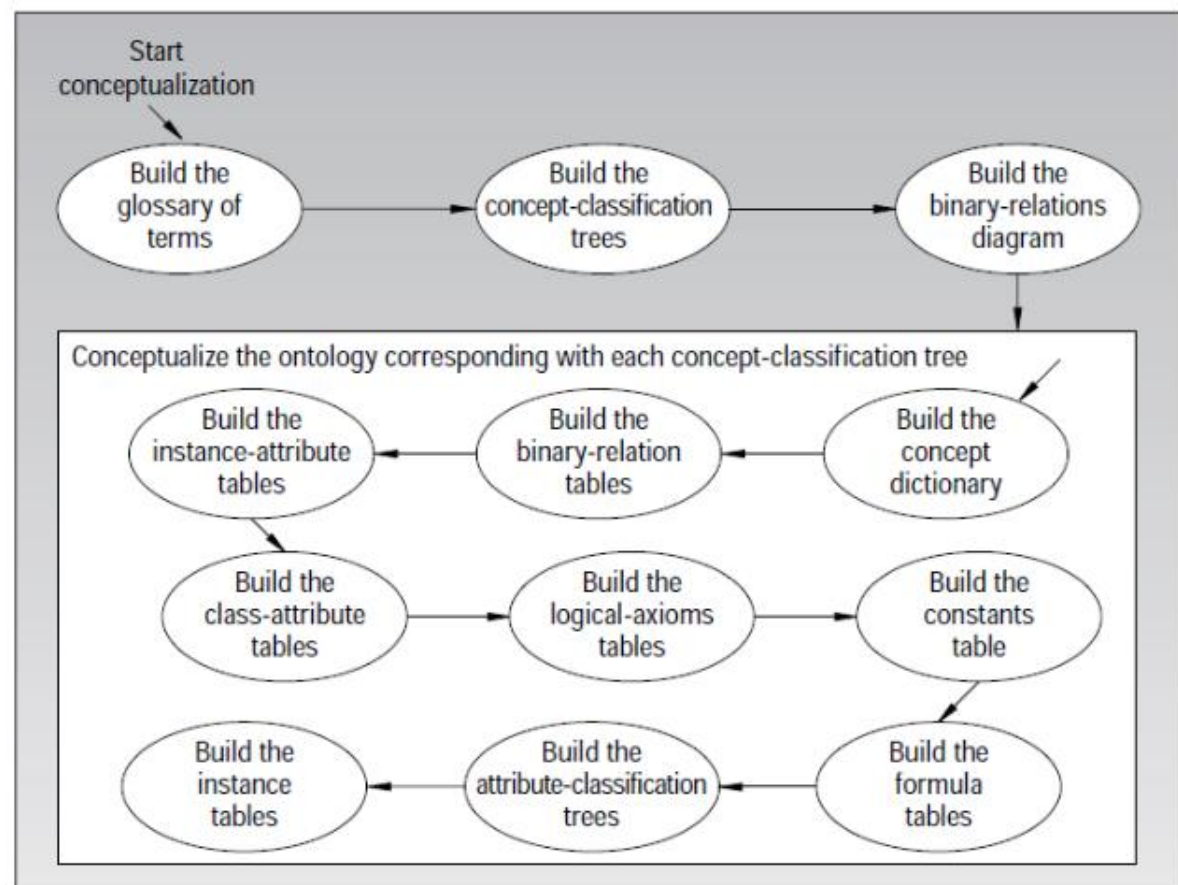


Figure 11 - Task of conceptualization process

Source: Fernandez et al., 1997

This task can be according Fernández et al. (1997) and Corcho et al. (2002):

1. **Build a glossary of terms** - included on the ontology, their natural language definition and their synonyms and acronyms
2. **Build the binary relation** - used to define the ad hoc relations between concepts of the ontology and also with concepts of other ontologies
3. **Build the concept dictionary** - is detailed, for each relation, it is specified its cardinality, inverse relation and mathematical properties, Instance and class attributes are also described in terms of their concept, value type, measurement unit, range, cardinality, value and related **axioms** (are logical expressions that are always true and are normally used to specify constraints) and **rules** (are generally used to infer knowledge in the ontology, such as attribute values, relation instances, etc.) that infer the value of this attribute or use it to infer other attributes.

In that case conceptualization is made in Part 3 entitled The Digital Library Reference Model Concepts and Relations in D3.2b The Digital Library Reference Model³ thus is not required, but some example are illustrated below in the figure 12 and figure 13 and also in the implementation and results chapter.

Although this stage is producing a conceptual model expressed in a series of well-defined outcomes for end users in order to determine whether or not an ontology is useful and usable for a particular application without inspecting its source code and compare the scope and integrity of several ontologies, their reuse and sharing, by the analysis of knowledge expressed in each concept.

3

Access in <https://www.coar-repositories.org/files/D3-2b-Digital-Library-Reference-Model.pdf>

C1 Resource

- . C2 Resource Identifier
- . C3 Resource Set
- . . C4 Result Set (also <isa> Information Object)
- . . C18 Collection
- . . C23 Group (also <isa> Actor)
- . C5 Resource Format
- . C19 Query
- . C20 Ontology

Figure 12 - Concept classification hierarchy

Source: Candela et al., 2011

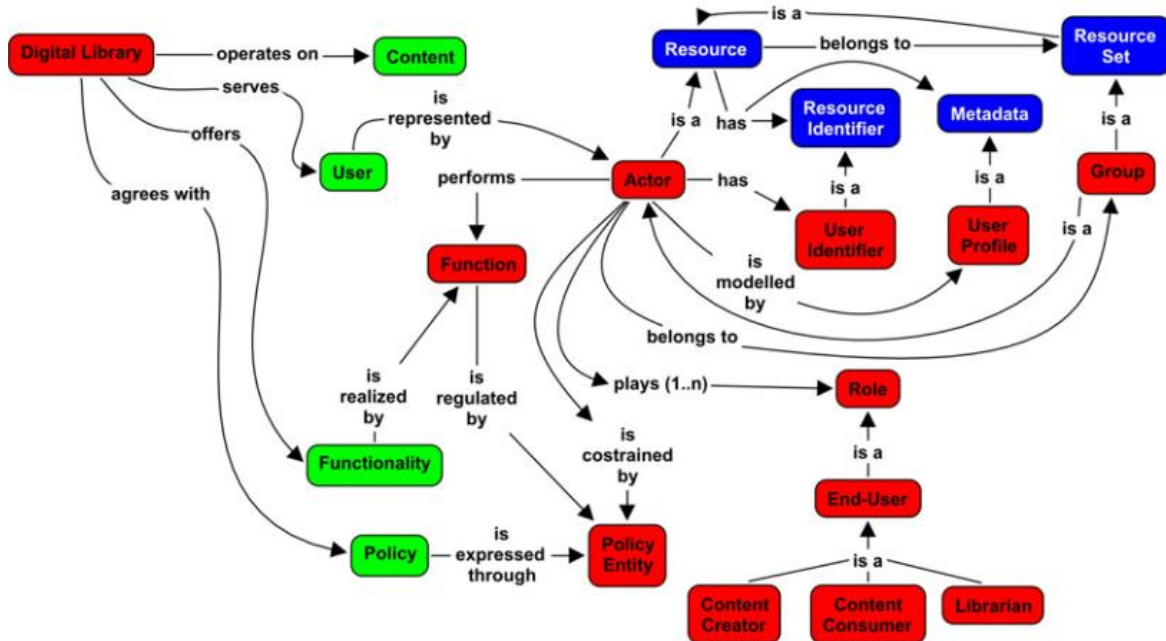


Figure 13- The Users Concepts

Source: Casarosa, 2007

3.4.3. Formalization

The goal of this activity is to formalize the conceptual model, conceptual model created is transformed into formal model, ie, is represented by a language of formal logic; Development

of ontologies exist that automatically implement the conceptual model in various ontology languages using translators, much of formalization tools is ever in conceptualization, especially in the logical axioms table, so the formalization is not a mandatory activity (Corcho et al., 2002 and González, 2005).

3.4.4. Implementation

This activity builds up computable models using ontology implementation languages, the conceptual model generated is implemented to be computable; an environment for developing ontologies is used here (Fernández et al.,1997, Corcho et al., 2002 and González, 2005).

The tool being used is as well as target implementation of the process is described in Chapter 4 entitled Implementation and Results.

3.4.5. Maintenance

At this stage the updates and corrections of possible errors can be necessary due to the needs of the ongoing development process or other processes that reuse this ontology in order to build other ontologies or applications (González, 2005).

Some authors like Fernández et al. (1997), Corcho et al. (2002) and González (2005) add one more stage it is also important in the process to build ontologies is the evaluation.

3.4.6. Evaluation

Evaluation means the completion of a technical judgment of the ontologies in your software environment and documentation with respect to a frame of reference for each phase and between phases of its life cycle. Ontologies should be evaluated before being used or reused. There are two types of evaluation, a technique, which is performed by developers, and user evaluation (Fernández et al.,1997, Corcho et al., 2002 and González, 2005).

Fernández et al.,1997 and González (2005) say that evaluation must include:

- **Ontology verification** refers to building the ontology correctly, that is, ensuring that its definitions implement correctly the requirements or function correctly in the real world.
- **Ontology validation** refers to whether the ontology definitions really model the real world for which the ontology was created.

- **Ontology assessment** is focused on judging the ontology from the user's point of view. Different types of users and applications require different means of assessing ontology.

This research is not expected to maintenance and even the evaluation of ontology developed, it will be left for future research.

Chapter 4 Designing and Implementation

4.1. Introduction

In order to have a single reference model for digital libraries, with clear exposition of entities and relationships, it is necessary to make up an ontology based on Delos Reference Model. This paragraph refers to the main components of the digital library ontology, describes the process of creating the Delos References Model, ontology building process using methodology, based on the W3C standard for create ontologies. The Delos ontology is formalized by using the ontology editor SKOS to generate the ontology code, the poolparty. The achieved result is Delos ontology which has two levels: the first levels have the tree “super” concepts include: DL, DLS, DLMS, in the second level the concept related each “super” concepts, called main concepts (DL (Content, Users, Functionality and Quality); DLS (Content, Users, Functionality, Policy and Quality), DLMS (User, Content, Functionality, Quality, Policy and Architecture)) as we can see in the figure 14.

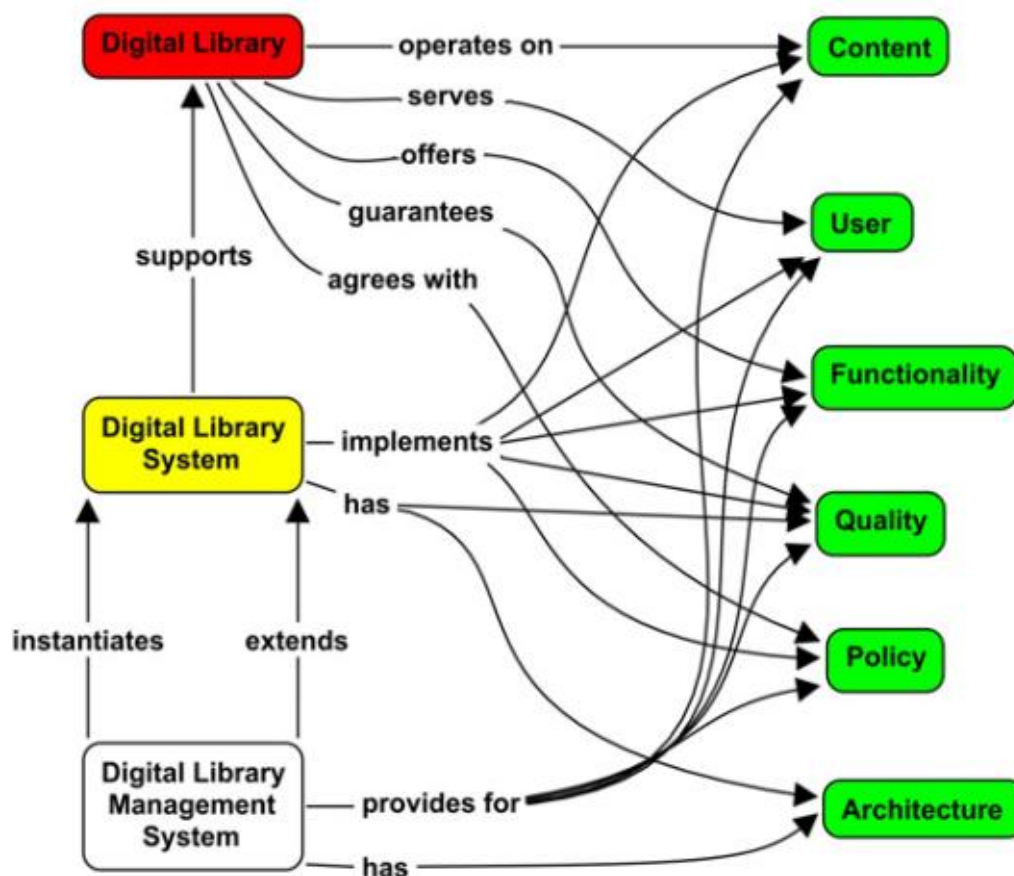


Figure 14 - The Reference Model Concepts

Source: Casarosa, 2007

The Delos References Model ontology methodology is constructed as follows:

4.2. Process for building the ontology

The fundamental rules for ontology design are complicated by the fact that we don't have one correct way to model a domain. Therefore in the ontology development it is necessarily an iterative process; concepts in the ontology should be close to objects (physical or logical) and relationships in one's domain of interest, etc. Assuming, the ontology-building process as follows: 1- determine the domain and scope of the ontology; 2 - consider reusing existing ontologies; 3- enumerate important terms in the ontology; 4 -define the classes and the class hierarchy; 5 -define the properties (slots) of classes; 6 - define the facets of the slots; and finally, 7- create instances (Noy and McGuinness, 2001).

This subchapter will identify the key concepts, relationships that are relevant to ontology, called ontology capture followed by the encoding, this part involves explicitly representing the knowledge acquired in the paragraph above. The process progresses to ontology capture, using ontology language SKOS and trying to follow the Noy and McGuinness (2001) ontology-building process as mentioned above.

4.2.1. Ontology capture

This paragraph will identify key concepts, relationships that are relevant to the ontology including identification of terms to refer to these concepts and relationships using a top-down approach, to performing this step. The top-down approach starting from the more generic concept and building a structure by specialization, the ontology is built by determining first the top concepts and specializing then. This approach is helpful for the reuse of ontologies and inclusion of high level philosophical considerations which can be very interesting for coherence maintenance (Roussey, 2005).

4.2.1.1. Concepts and Relationships

The Digital Library Ontology has main components that include: Classes (are interpreted as sets that contain individuals with common characteristics and sometimes, classes can organise into a

superclass and subclass hierarchy), properties (represent relationships, the ways objects can relate to other objects ;), and individuals (are instances or objects).

In this paragraph we will only present the super classes, main classes, main relationships, and also some subclasses for more information about other subclasses can be found in Chapter 3 entitled "The Digital Library Reference Model Concepts and Relations" document presented by Candela et al. (2011).

Super Classes:

1. **Digital Library** - an organisation, which might be virtual, that comprehensively collects, manages and preserves for the long term rich information objects, and offers to its Actors specialised Functions on those Information Objects, of measurable quality, expressed by Quality Parameters, and according to codified Policies. DL is a complex universe and usually the term ‘digital library’ is used with many different semantics.

Relationships:

- Digital Library <manage> Resource
- Digital Library <manage> Information Object
- Digital Library <serve> Actor
- Digital Library <offer> Function
- Digital Library <agreeWith> Policy
- Digital Library <tender> Quality Parameter
- Digital Library System <support> Digital Library
- Digital Library is <definedBy> Resource Domain
- Digital Library is <definedBy> Content Domain
- Digital Library is <definedBy> User Domain
- Digital Library is <definedBy> Functionality Domain
- Digital Library is <definedBy> Policy Domain
- Digital Library is <definedBy> Quality Domain

2. Digital Library Management System - a generic software system that provides the appropriate software infrastructure both 1 -to produce and administer a Digital Library System incorporating the suite of Functions considered fundamental for Digital Libraries, and 2 - to integrate additional Software Components offering more refined, specialised or advanced functionality. The Digital Library Management System (DLMS) is the system that provides DL Designers, DL System Administrators and DL Application Developers with Functions supporting their tasks.

Relationships:

- Digital Library Management System <deploy> Digital Library System
- Digital Library Management System <extend> Digital Library System
- Digital Library Management System is <definedBy> Resource Domain
- Digital Library Management System is <definedBy> Content Domain
- Digital Library Management System is <definedBy> User Domain
- Digital Library Management System is <definedBy> Functionality Domain
- Digital Library Management System is <definedBy> Policy Domain
- Digital Library Management System is <definedBy> Quality Domain
- Digital Library Management System is <definedBy> Architecture Domain

3. Digital Library System - a software system based on a given (possibly distributed) Architecture and providing all the Functions required by a particular DL. Actors interact with a DL through the corresponding DLS. The DLS is the running software system serving the DL. Like any running software system, it is characterised by two facets, its Software Architecture and its System Architecture.

Relationships:

Digital Library System <support> Digital Library

Digital Library System is <definedBy> Resource Domain

Digital Library System is <definedBy> Content Domain

Digital Library System is <definedBy> User Domain

Digital Library System is <definedBy> Functionality Domain

Digital Library System is <definedBy> Policy Domain

Digital Library System is <definedBy> Quality Domain

Digital Library System is <definedBy> Architecture Domain

Digital Library System <has> Software Architecture

Digital Library System <has> System Architecture

The relationship between DL and DLMS is that the DLMS supports DL with all his services and functionality and also happened with the relationship between DL and DLS;

Main Classes:

4. Resource Domain - an identifiable entity in the DL universe. The Web is intended as an information space in which the items, referred to as resources, are identified by a unique and global identifier called Uniform Resource Identifier (URI). The Resource Model presented here starts from Web architecture and adds domain-specific aspects needed to accommodate DL requirements. The Resource concept is abstract, in the sense that it cannot be instantiated directly but only through the instantiation of one of its specialisations. All the different types of Resources share many characteristics and ways in which they can be related to other Resources, as we can see in the figure 15 below.

Relationships:

- Resource must have at least one unique Resource Identifier (<identifiedBy>);
- Resource <hasPart> Resource;
- Resource is <associatedTo> Resource for a certain Purpose;
- Resource <hasFormat> Resource Format;
- Resource <hasMetadata> Information Object;
- Resource <hasAnnotation> Information Object to a certain Region;
- Resource may be regulated by (<regulatedBy>) Policy;
- Resource may have (<hasQuality>) Quality Parameter;

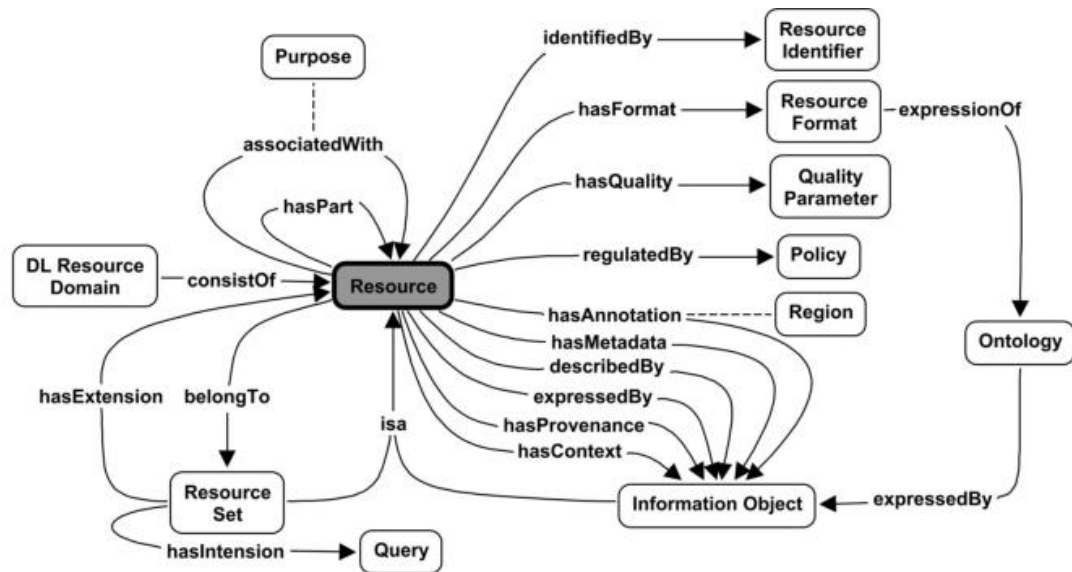


Figure 15 - DL Resource Domain Concept Map

Source Candela et al. (2011)

5. Content Domain - one of the six main concepts characterising the DL universe. It represents the various aspects related to the modelling of information managed in the DL universe to serve the information needs of the Actors. The Content concept represents the information that DL handle and make available to their Actors. It is composed of a set of Information Objects organised in Collections.

Relationships:

- Digital Library <definedBy> Content Domain
- Digital Library System <definedBy> Content Domain
- Digital Library Management System <definedBy> Content Domain
- Content Domain <consistOf> Information Object
- Content Domain <organisedIn> Collection

6. Information Object - is the main Resource of the Content Domain. An Information Object is a Resource identified by a Resource Identifier as we can see in the figure 16. It must belong to at least one Collection. It may have Metadata, Annotations and multiple Editions, Views, Manifestations, which are also represented as Information Objects. In addition, it may have Quality Parameters and Policies. The notion of Information Object is the main entity

populating the Content Domain. The management of this kind of entities dedicated to capture any form of information is in fact the purpose of the DLD since the beginning. Information Objects are representations of raw data organized information items that are stored in the DL ‘system’ with the objective to provide its users (Actors) with the data they needs in an organised and seamless way.

Relationships:

- Information Object <isa> Resource;
- Information Object <hasFormat> Resource;
- Information Object is <identifiedBy> Resource Identifier;
- Information Object <belongTo> Collection;
- Information Object <hasMetadata> Information Object (Metadata);
- Information Object <hasAnnotation> Information Object (Annotation);
- Information Object <hasEdition> Information Object;
- Information Object <hasView> Information Object;
- Information Object <hasManifestation> Information Object;
- Information Object <hasQuality> Quality Parameter;
- Information Object is <regulatedBy> Policy.

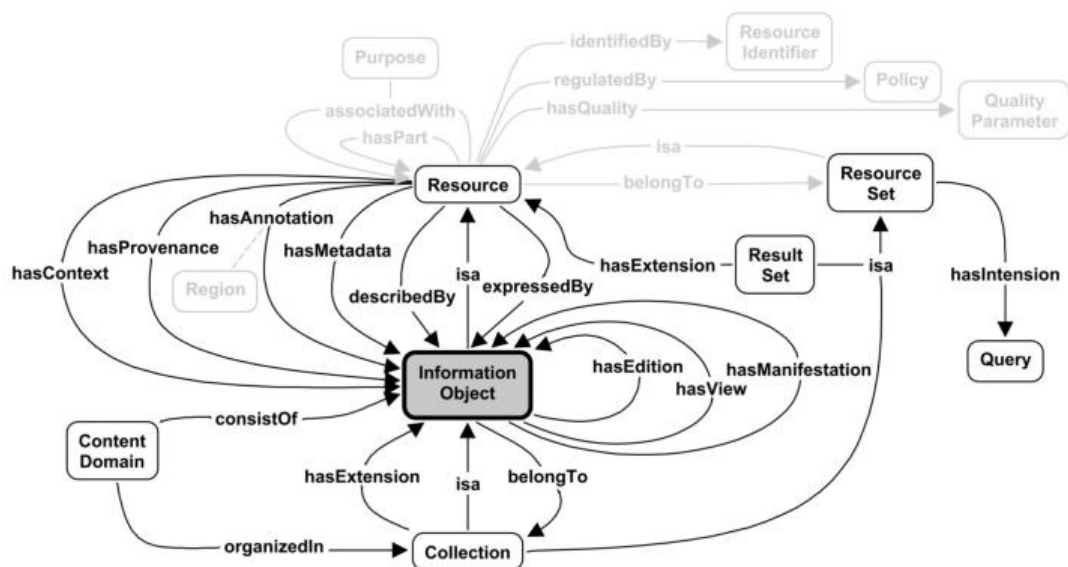


Figure 16 - Content Domain

Source: Candela et al. (2011)

7. Collection - a content Resource Set. The ‘extension’ of a collection consists of the Information Objects it contains. A Collection may be defined by a membership criterion, which is the ‘intention’ of the collection. Collections represent the classic mechanism to organise Information Objects and to provide focused views of the Digital Library Information Object Resource Set. These focused views enable Actors. The definition and identification of the Information Objects constituting a Collection (the collection extension) is based on a characterisation criterion (the collection intention).

Relationships:

- Collection <isa> Resource Set
- Collection <isa> Resource
- Information Object <belongsTo> Collection
- Collection <hasIntension> Query
- Collection <hasExtension> Resource Set (set of Information Object)

8. User Domain - one of the six main concepts characterising the Digital Library universe. It represents the various aspects related to the modelling of entities, either human or machines, interacting with any DL ‘system’. The User Domain concept represents the Actors (whether human or not) entitled to interact with Digital Libraries. The aim of Digital Libraries is to connect such Actors with information (the Information Objects) and to support them in consuming already available information and produce new information (through the Functions).

Relationships:

- Digital Library <definedBy> User Domain
- Digital Library System <definedBy> User Domain
- Digital Library Management System <definedBy> User Domain
- User Domain <consistOf> Actor

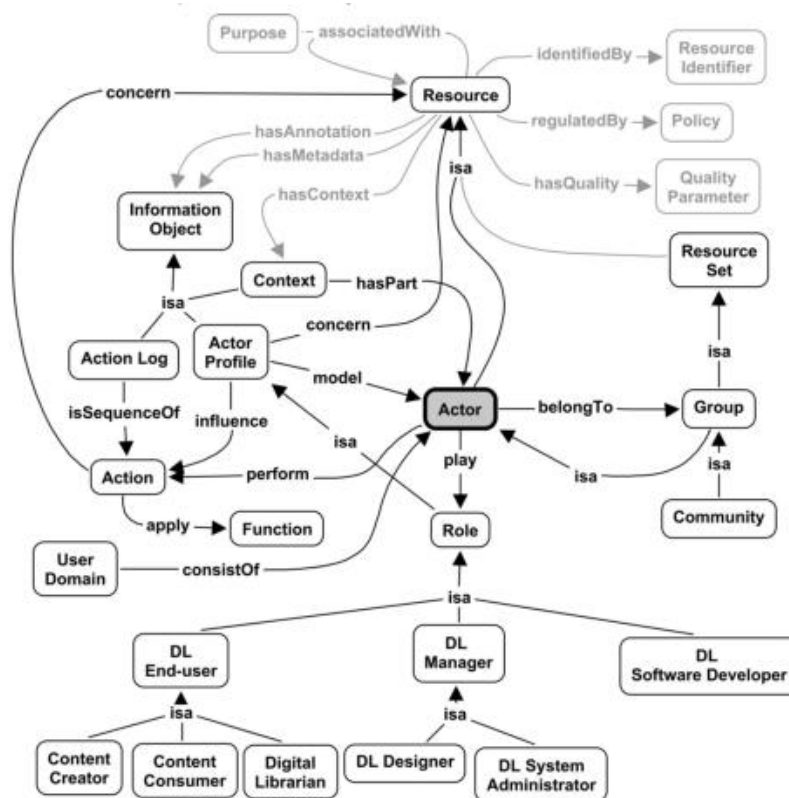


Figure 17 - User Domain concept maps

Source Candela et al. (2011)

9. Functionality Domain - one of the six main concepts characterising the Digital Library universe. It represents the various aspects related to the modelling of facilities/services provided in the Digital Library universe to serve Actor needs as we can see in the figure 18 below. The Functionality Domain concept represents the services that Digital Libraries offer to their Actors. The set of facilities expected from Digital Libraries is extremely broad and varies according to the application context.

Relationships:

- Digital Library <definedBy> Functionality Domain
- Digital Library System <definedBy> Functionality Domain
- Digital Library Management System <definedBy> Functionality Domain
- Functionality Domain <consistOf> Functions

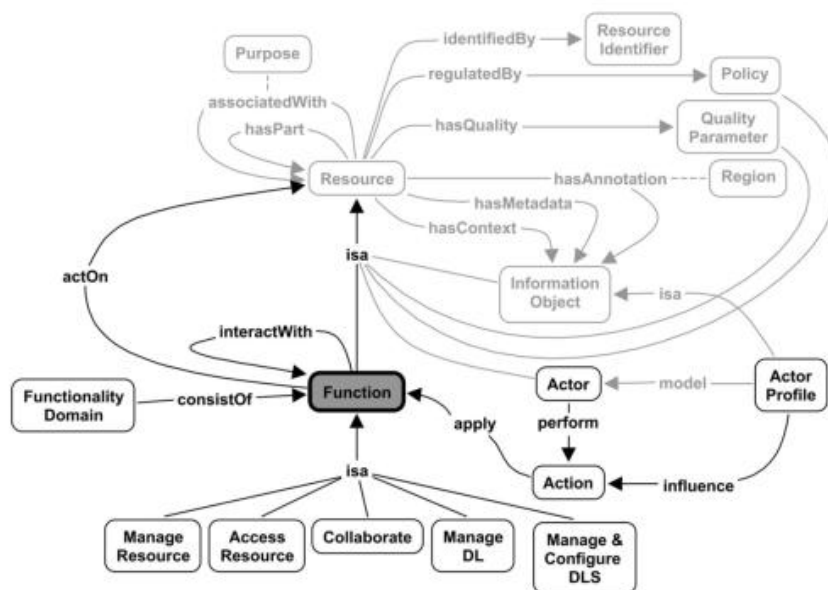


Figure 18 - Functionality Domain Concept Map

Source candela et al. (2011)

10. Policy Domain - one of the six main concepts characterising the DL universe. It represents a set of guiding principles designed to organise actions in a coherent way and to help in decision making as we can see in the figure 20. The term Policy usually refers to a set of principles that describe the acceptable processes and/or procedures within an organisation. Policy Domain affects how the complete system is designed and how it functions.

Relationships:

- Digital Library <definedBy> Policy Domain
- Digital Library System <definedBy> Policy Domain
- Digital Library Management System <definedBy> Policy Domain
- Policy Domain <consistOf> Policy

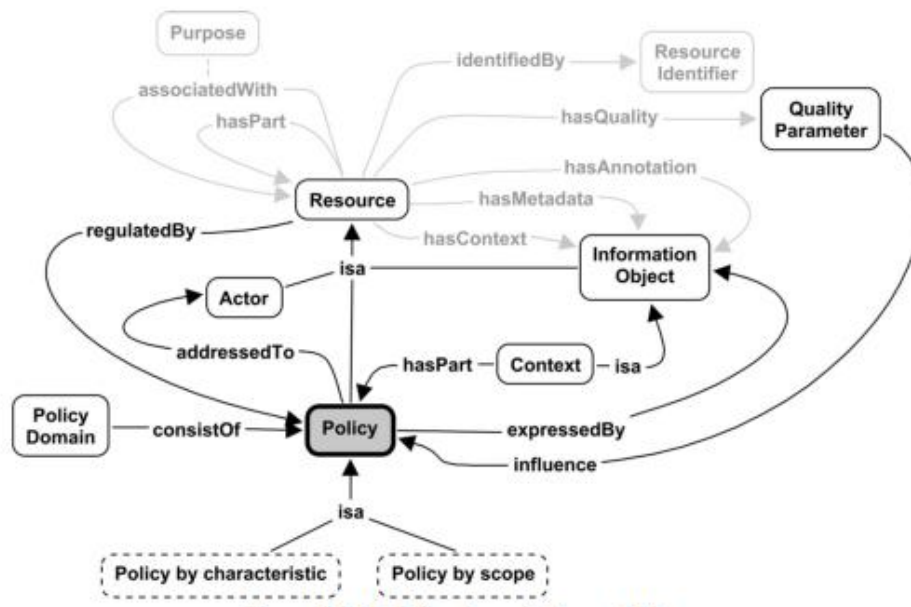


Figure 19 - Policy Domain

Source Candela et al. (2011)

11. Quality Domain - one of the six main concepts characterising the Digital Library universe. It captures the aspects that permit considering DL ‘systems’ from a quality point of view, with the goal of judging and evaluating them with respect to specific facets. It represents the various aspects related to features and attributes of Resources with respect to their degree of excellence. The Quality Domain concept represents the various facets used to characterise, evaluate and measure Digital Libraries, Digital Library Systems, Digital Library Management Systems and their Resources from a quality point of view.

Relationships:

- Digital Library <definedBy> Quality Domain
- Digital Library System <definedBy> Quality Domain
- Digital Library Management System <definedBy> Quality Domain
- Quality Domain <consistOf> Quality Parameters

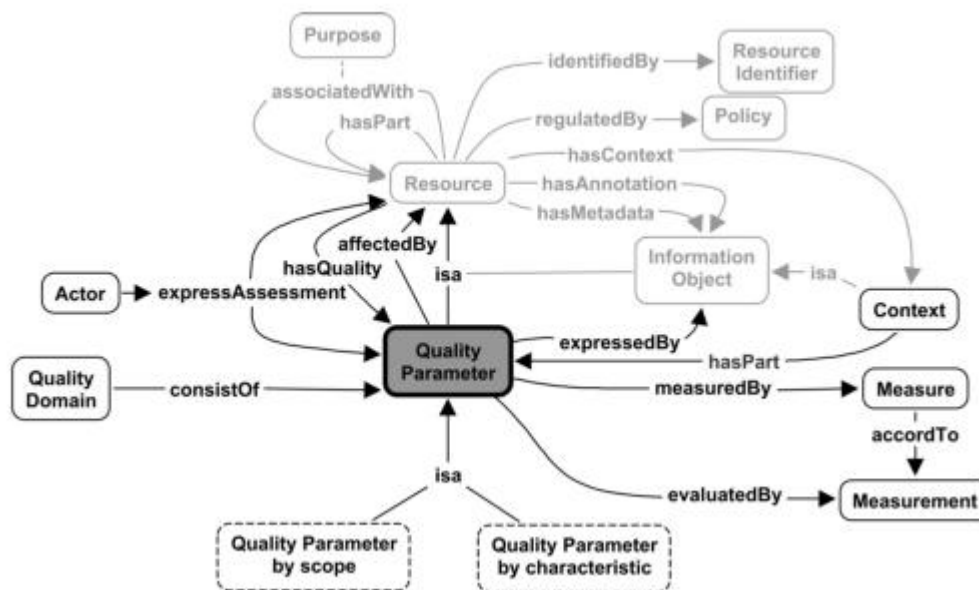


Figure 20 - Quality Domain Concept Map

Source Candela et al. (2011)

11. Architecture Domain - one of the six main concepts characterising the Digital Library universe. It represents the various aspects related to the software systems that concretely realise the DL universe. The Architecture Domain encompasses concepts and relationships characterising the two software systems that play an active role in the DL universe, i.e., DLSs and DLMSs as we can see in the figure 21 below.

Relationships:

- Digital Library <definedBy> Architecture Domain
- Digital Library System <definedBy> Architecture Domain
- Digital Library Management System <definedBy> Architecture Domain
- Architecture Domain <consistOf> Architectural Component

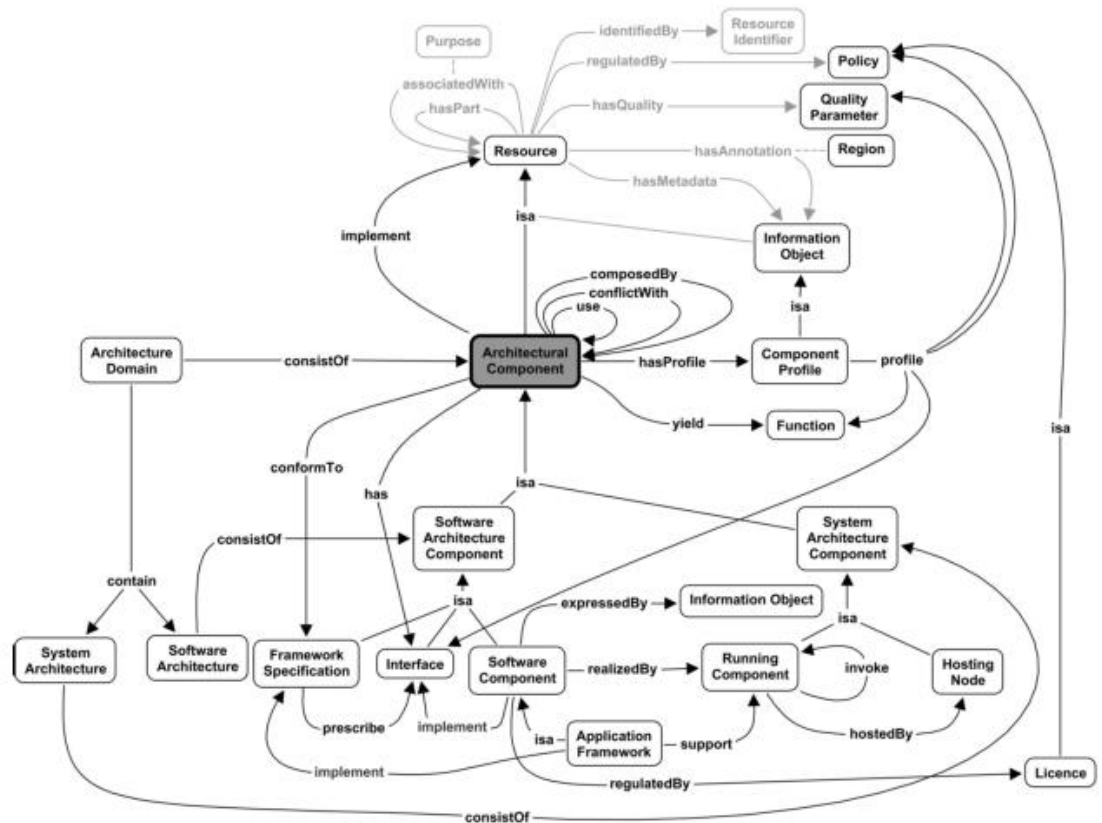


Figure 21 - Architecture Domain Concept Map

Source Candela et al. (2011)

Subclasses:

Here we present only some subclasses of a set of many, they don't follow any order or degree of importance, they are just examples.

1. **Actor Profile** - may belong to a distinct Actor or it may model more than one Actor. An Actor Profile is an Information Object that models an Actor by potentially capturing a large variety of the Actor's characteristics;

Relationships:

- Actor Profile <isa> Information Object
- Actor Profile <model> Actor
- Actor Profile <concern> Resource
- User Profiling <create/update> Actor Profile
- Actor Profile <influence> Action

- 2. Resource set** - is defined for some management or application purpose as a set of Resources, is in turn a Resource. The grouping of Resources is required in many operations of a Digital Library.

Relationships:

- Resource Set <isa> Resource
- Resource <belongsTo> Resource Set

- 3. Role** - is a kind of pre-packaged generic profile and may be seen as a packet of statements identifying the kind of Functions an Actor, consist of a set of functions within the context of an organisation with some associated semantics regarding the authority and responsibility conferred on the user assigned role. Is eligible to perform within the system;

Relationships:

- Actor <play> Role
- Role <isa> Actor Profile
- DL End-user <isa> Role
- Content Creator <isa> Role
- Content Consumer <isa> Role
- Digital Librarian <isa> Role
- DL Manager <isa> Role
- DL Designer <isa> Role
- DL System Administrator <isa> RoleDL Software Developer <isa> Role

- 4. Function** - captures any processing that can occur on Resources and is typically perceived as a result of an activity of an Actor in a Digital Library. It can possibly involve any type of Resource and can potentially be performed by any kind of Actor;

Relationships;

- Function <isa> Resource
- Function is <identifiedBy> Resource Identifier (inherited from Resource)
- Function is <influencedBy> Actor Profile

- Function is <influencedBy> Policy
- Function <actOn> Resource
- Function is <regulatedBy> Policy (inherited from Resource)
- Function <hasQuality> Quality Parameter (inherited from Resource)
- Actor <perform> Function
- Actor <modify> Function

Main relationships

Relationships here describe the relationships between two objects (e.g.: the relationship between DL and DLMS is Digital Library Management System “support” Digital Library). Here we divide the relationships in: generic relationships and relationships inherent to each class, some of this relationship will be present and also the definition of each of them:

Generic relationships - are relations that can be related to any class within the ontology:

- **isa** - the relation connecting any concept to the concept it is a sub-concept of.
For example: Information Object <isa> Resource - this is mean that an Information Object is a ‘specialisation’ of Resource and Resource is a ‘generalisation’ of An Information Object;
- **identifiedBy** - the relation connecting a Resource to its Resource Identifier. Each Resource must have at least one Resource Identifier, this relation captures the Resource Identifier attached to each Resource for this identification purpose. Each Resource Identifier can be assigned to one Resource only;
- **hasFormat** - the relation connecting a Resource to its Resource Format, which establishes the attributes or properties of the Resource, their types, cardinalities, etc. and a Resource must have one format only, whereas the same format can (obviously) be used by many Resources. This relation is commonly called ‘instance of’ in object models;
- **expressionOf** - the relation connecting a Resource Format to the Ontology that defines the terms of the schema and states the main constraints on them. A schema gives a

concrete status to the terms abstractly defined in an ontology, by establishing implementation details such as the data type of the primitive concepts of the ontology;

- **hasMetadata** - the relation connecting Resources to Information Objects for management purposes. In classic DL models, Metadata is a concept that is a primary notion modelling a clearly defined category of objects in the domain of discourse. Nevertheless, it depends from the context whether an object is or is not Metadata;
- **describedBy** - the relation connecting Resources to Information Objects describing them. This is a specialisation of the <hasMetadata>. A Resource can be associated with many descriptive Information Objects;
- **hasPart** - the relation connecting Resources to their constituent Resources. This 'part of' association may have two different natures: the aggregative and the compositional one. In the aggregative nature, the single parts stand by themselves and may be constituents of any number of Resources. In the compositional nature, the whole strongly owns its parts, for instance, if the whole Resource is copied or deleted, its parts are copied or deleted along with it.

Exclusive class relationships - are relations that are exclusive or related to one class:

User:

- **play** - is the relation connecting an Actor to a Role that defines the Role(s) of the Actor; Actors can play different Roles in the DL;
- **isSequenceOf** - the relation connecting Action Log to Action, this relation indicates that an Action Log consists of a set of Actions;

Content Relations

- **hasEdition** - the relation connecting Information Objects to the Information Objects that realise them along the time dimension. In classic DL models, Editions represent the different states of an Information Object during its lifetime, i.e., they play the role usually assigned to versions;

- **hasView** - the relation connecting Information Objects to the Information Objects that are Views of them. The concept of View captured by this relation fits very well with those used in the database world;

Funcionality:

- **interactWith** - the relation connecting Functions to Functions that expresses the interaction between them;
- **influencedBy** - the relation connecting Functions to Actor Profiles that expresses the fact that Functions are influenced by specific user characteristics;

Policy:

- **regulatedBy** - the relation connecting Resources to the Policies regulating them, i.e. is used to show what Resources are being regulated by a specific Policy;
- **addressedTo** - the relation connecting Policy to the Actor(s) the Policy is conceived for. Every Policy is conceived to drive the behaviour of the Actor(s).

Quality:

- **evaluatedBy** - is the relation defines the process followed to determine the assessment of a Resource with respect to the specific feature taken into consideration by a Quality Parameter, this relation takes into account that different Measurements can be used for assessing the same Quality Parameter;
- **measuredBy** - the action of, and the value obtained by, measuring a Quality Parameter (Resource that indicates, or is linked to, performance or fulfilment of requirements by another Resource) in accordance with a selected Measurement;

Architecture

- **implement** - the relation connecting Architectural Components to the Resources they realise. Relation associates notion of Resource with the Architectural Component (another Resource) that makes it real, put it into effect. The same Resource can be implemented by many Architectural Components as well as an Architectural Component can implement many Resources;

- hostedBy - this relation is a specialisation of the <implement> relation in the context of Running Components and Hosting Nodes; is the relation connecting Running Components to the Hosting Nodes physically hosting them;;

4.2.2. Process to Ontology encoding

The coding process, involves explicitly representing the knowledge acquired in paragraph 4.2.1 in a formal language in this research will be SKOS and also the tools is Protégé version 4.3, for the representation of ontology in SKOS, will be using a plugin for Protégé, the SKOSED version 2.0.

4.2.2.1. Tools and languages

Ontology languages are formal languages used for building ontologies. They allow the encoding of knowledge about specific domains and often include reasoning rules that support the processing of which is knowledge. Ontology languages are usually declarative languages, almost always are generalizations of language frameworks, and are commonly based on either first-order logic or logic description (Kalibatiene & Vasilecas, 2011 and «Ontology language», 2014). The same authors in their research present four most popular ontology languages: KIF, OWL, RDF + RDF(S) and DAML+OIL, but leave out a lot of ontology language, like: Ontology Inference Layer (OIL), SHOE, DOGMA (Developing Ontology-Grounded Methods and Applications), OKBC (Open Knowledge Base Connectivity) and etc., divide according two categories: **traditional ontology languages**, they are: languages based on first-order predicate logic (KIF - Knowledge Interchange Format, CycL - used to represent the knowledge stored in the Cyc Knowledge Base), frame-based languages (Ontolingua, F-logic and OCML), description logic (DL) based languages (Loom - language and environment for constructing intelligent applications); Web standards, which are used to facilitate interchange on the Internet, and ontology languages, which are web standard compatible, are named **Web-based ontology languages**: OWL, RDF + RDF(S) and DAML+OIL (Corcho & Gómez-Pérez, 2000; Corcho et al, 2003; Kalibatiene & Vasilecas, 2011 and «Ontology language», 2014).

However, Kalibatiene & Vasilecas (2011) say that, particular languages can be assigned to both categories, i.e. they are based on a particular Web standard and a particular paradigm, like frames or first-order predicate logic. For example, OWL DL is based on RDF and description logic as we can see in the figure 22.

There are also a lot of software tools related to ontologies, software for their creation and manipulation. Many ontology editors could be found on Internet. Some of them like: Apollo, OntoStudio, Protégé, Swoop, TopBraid Composer Free Edition, OilEd, RDFed and etc. are used from huge number of people.

A comparative table (see table 1) was proposed by several authors, but let's take two of them as an example, Mc Leod (2006) and Alatrish (2013). A comparison could be done by using different criteria like: generality, expressiveness, complexity, documentation, scalability and etc.

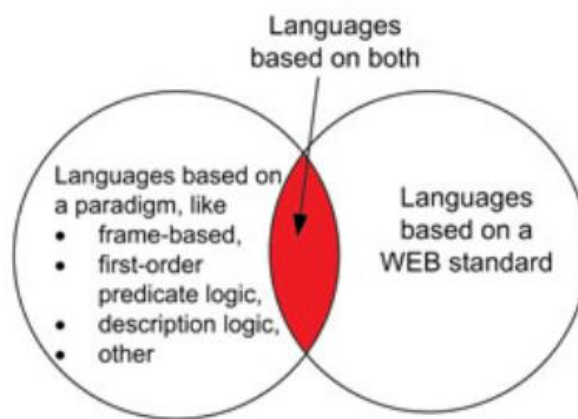


Figure 22 - Ontology languages

Source: Kalibatiene & Vasilecas (2011)

	Import format	Export format	GUI	Consistency check	Multi-user	Web support	Merging
Protégé 2000	XML, RDF(S), XML schema	XML, RDF(S), XML schema, FLogic, CLIPS, Java, HTML	Via plug-ins like GraphViz and Jambalaya	Via plug-ins like PAL and FaCT	Limited (multi-user capability added to it in 2.0 version)	Via Protégé-OWL plug-in	Via Anchor-PROMPT plug-in
OilEd	RDF(S), OIL, DAML+OIL	RDF(S), OIL, DAML+OIL, SHIQ, doty, HTML	No	Via FaCT	No	Very limited name spaces	No
Apollo	OCML, CLOS	OCML, CLOS	No	Yes	No	No	No
RDFedt	RDF(S), OIL, DAML, SHOE	RDF(S), OIL, DAML, SHOE	No	Only checks writing mistakes	No	Via RSS	N/A
OntoLingua	IDL, KIF	KIF, CLIPS, IDL, OKBC syntax, Prolog syntax	No	Via Chimaera	Via write-only locking, user access levels	Yes	N/A
OntoEdit (free version)	XML, RDF(S), Flogic, DAML+OIL	XML, RDF(S), Flogic, DAML+OIL	Yes	Yes	No	Yes	N/A
WebODE	RDF(S), UML, DAML+OIL, OWL	RDF(S), UML, DAML+OIL, OWL, Prolog, X-CARIN, Java/Jess	Form-based graphical user interface	Yes	By synchronization, authentication, and access restriction	Yes	Via ODEmerge
KAON	RDF(S)	RDF(S)	No	Yes	By concurrent access control	Via KAON PORTAL	No
ICOM	XML, UML	XML, UML	Yes	Via FaCT	No	No	With inter-ontology mapping
DOE	XSLT, RDF(S), OIL, DAML+OIL, OWL, CGXML	XSLT, RDF(S), OIL, DAML+OIL, OWL, CGXML	No	Via type inheritance and detection of cycles in hierarchies	No	Load ontology via URL	No
WebOnto	OCML	OCML, GXL, RDF(S), OIL	Yes	Yes	With global write-only locking	Web based	N/A
Medius VOM	XML schema, RDF, DAML+OIL	XML schema, RDF, DAML+OIL	UML diagrams via Rose	With a set of ontology-authoring wizards	Network based	Via read-only browser support from Rose	Limited (only native Rose model)
LinKFactory	XML, RDF(S), DAML+OIL, OWL	XML, RDF(S), DAML+OIL, OWL, HTML	No	Yes	Yes	Yes	Yes
K-Infinity	RDF	RDF	With graph editor	Yes	Network based	No	N/A

Table 1 - Comparison between Ontology Editors

Source: Mc Leod (2006) and Alatrish (2013)

4.2.2.1.1. SKOS - Simple Knowledge Organization System

“Simple Knowledge Organisation System seems to be the most promising representation for the type of knowledge models used in digital libraries” (Lacasta et al., 2007).

SKOS is a World Wide Web Consortium (W3C) recommended standard for representing and publishing Knowledge Organization Systems (KOS) on the Web, using a vocabulary and data model expressing Knowledge Organization Systems (KOS's) such as thesauri and classification schemes for referencing and re-use in Semantic Web applications. Is one of various ways to represent a model for representing such vocabularies on the Semantic Web. KOS encapsulates a wide variety of known tools, but can generally be categorized as classification systems, thesauri, taxonomies, and a subject heading systems. KOS has been classically used in libraries and information sciences as a way of indexing large volumes of documents in order to facilitate document retrieval and navigation (La Fuente, 2008; W3C, 2009; Putkey, 2011; Haslhofer et al., 2013 and Baker et al., 2013).

SKOS is an open collaboration initiated by the Semantic Web Advanced Development for Europe project (SWAD-Europe), funded by the EU-IST 5th framework program and initiated in 2003 (La Fuente, 2008). SKOS provides a model to represent and use vocabularies and ontologies in the framework of the Semantic Web, using the Resource Description Framework (RDF). These models (SKOS data) are expressed as RDF triples. This means that concepts may be subject or object and related via a SKOS property which would be the predicate. As RDF triples, SKOS concepts can be identified using URIs. These URIs can be defined according standard persistent identifier systems, although, they don't require the use of persistent identifiers but in a Linked Open Data perspective, their use is highly recommended (W3C, 2009; La Fuente, 2008; Leroi & Holland, 2010 and Baker et al., 2013)

Encoding this information in RDF allows it to be passed between computer applications in an interoperable way. The SKOS data model enables features listed above identifying, labelling, documenting, linking, and mapping concepts, and aggregating concepts into concept schemes or collections by defining the elements depicted in Figure 23 shown below (W3C, 2009; La Fuente, 2008 and Baker et al., 2013).

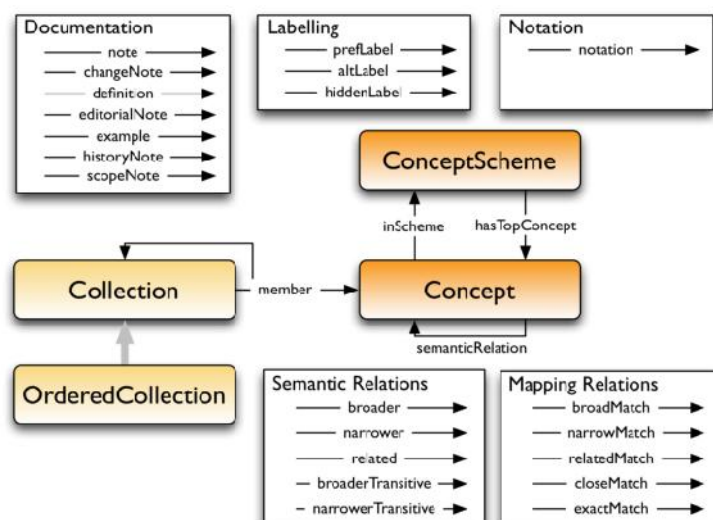


Figure 23 - Main elements of the SKOS data model

Source: Baker et al. (2013)

The SKOS data model provides a standard way of migration featuring low cost for porting existing knowledge organization for the Semantic Web systems. SKOS also provides a lightweight, intuitive language for developing and sharing new knowledge organization systems. It may be used alone or in combination with formal knowledge representation languages such as Web Ontology Language, i.e. SKOS is based on the RDF specification and enable a migration towards OWL ontologies (W3C, 2009).

The purpose of SKOS is to share and link KOS via the Web and allow semantic interoperability between different types of terminologies and languages. As a Semantic Web compliant format, SKOS is concept-oriented, this means that the fundamental elements of a terminology designed in SKOS is the concept, not the term that expresses this concept (Leroi & Holland, 2010 and Haslhofer et al., 2013).

The SKOS data model consists of three main components: **classes**, **properties** and **relations**, and always start with the prefix “**skos:**”

According to W3C (2009), Leroi & Holland (2010) and Cox, Yu and Rankine (2014), SKOS uses the following properties to identify values:

- Concept is skos:Concept - a concept can be defined as an idea, notion or unit of thought and can be SKOS concept scheme and SKOS collections;

- Concept scheme is `skos:ConceptScheme` - is a way to bring together several concepts. An individual concept scheme roughly corresponds to the notion of an individual thesaurus, classification scheme or any other knowledge organization system, a same concept can be part of more than one concept scheme;
- Concept collections is a `skos:Collection` or `skos:OrderedCollection` (can also be used in the case where the order of the concepts within the collection has an importance)
- Identifiers are necessary in order to each concept must be identified in a unique way to avoid any ambiguity; the identifiers are introduced by a specific RDF property:
 - Resources is `rdf:resource`.
- Lexical label:
 - Preferred label is a `skos:prefLabel` - property corresponds to the notion of descriptor from the standards for the elaboration of the ontology;
 - Alternative label is a `skos:altLabel` - are mainly used to give synonyms to the preferred label or other ways to refer to this preferred label;
 - Hidden label is a `skos:hiddenLabel` - property, may be used for mentioning the misspellings of preferred or alternative labels but also for mentioning obsolete forms of a term.
- Notation is a `skos:notation` - are symbols or codes that are not recognizable or understandable in any natural language;
- Documentation properties is a variety of possibilities to provide information related to concepts:
 - Note is a `skos:note` - provide general documentation on a concept;
 - Change note is a `skos:changeNote` - serve the purpose of administration and maintenance;
 - Definition is a `skos:definition` – providing information on the concept for a better understanding of its meaning;
 - Editorial note is a `skos:editorialNote` - serve the purpose of administration and maintenance;
 - Example is a `skos:example` – providing information on the concept for a better understanding of its meaning;

- History note is a `skos:historyNote` – providing information on the concept for a better understanding of its meaning;
- Scope note is a `skos:scopeNote`;

Semantic relations are connections between different concepts. These semantic relations play a crucial role for defining concepts and there are two different categories of semantic relation:

- Hierarchical:
 - Narrower is a `skos:narrower` - used to assert that a concept has a more specific meaning;
 - Broader is a `skos:broader` - property is used to assert that a concept has more general meaning;
- Associative:
 - Relates is a `skos:related` - is used to assert an associative link between two concepts;

SKOS provides several mapping properties for making alignment between concepts from different concept schemes:

- Close match is a `skos:closeMatch` – is used to make a mapping link between concepts that are very similar or equal;
- Exact match is a `skos:exactMatch` - is used to make a mapping link between concepts that are very similar or equal;
- Broad match is a `skos:broadMatch` - are used for a hierarchical mapping link between concepts;
- Narrow match is a `skos:narrowMatch` - are used for a hierarchical mapping link between concepts;
- Relates match is a `skos:relatedMatch` - is used for an associative one;

4.2.2.1.2. Poolparty

PoolParty is an open source platform that follows the standards of the W3C which seeks to implement the Semantic Web. This, through its components, provides an API that delivers, working with service, access and / or interacts with other applications in the context of knowledge representation following the Semantic Web Standards. It is also a thesaurus management system and a SKOS editor for the Semantic Web including text analysis functionalities and Linked Data capabilities (Cox, Yu and Rankine, 2014 and «PoolParty (W3C) », 2015).

It consists of: 1 - PPT - vocabularies server; 2 -PPX - the powerful entity extractor and text mining service; and 3 - PPS - the PoolParty Search Server used for smart end-user applications.

As already mentioned the PoolParty works as a service and following the W3C standards (Linked Data Principles) also provides good integration with other tools as well as its reuse of graphics created by it, sample and SKOS SPARQL, or integration with concrete Sharepoint, Drupal and WordPress. PoolParty is written in Java and uses the SAIL API3, whereby it can be utilized with various triple stores, which allows for flexibility in terms of performance and scalability (Schandl and Blumauer, 2010).

So, it is a very intuitive and easy tool for modelling ontologies especially in SKOS. The enterprise version for web was used to create SKOS Delos references model.

4.3. Implemetation

In this section we present the representation of concepts and relationships, of Delos reference model for digital libraries in SKOS. Here some examples will be present. The complete ontology is available in this link below:

<<https://drive.google.com/open?id=0B7nIdhf3fVkdDcGZNRDY3bUNhQWs&authuser=0>>

4.3.1.Main components of Digital Library SKOS representation

As we highlighted above SKOS data model consists of three main components: **classes**, **properties** and **relations**, and always start with the prefix “**skos:**” we will present the representation of main components of the Delos references model SKOS data model other components can be seen in annex entitled RDFS file.

Classes/Concept/Proprieties and Relation

A SKOS class concept can be seen as an idea or notion; a unit of thought. However, what constitutes a unit of thought is subjective, and this setting is intended to be suggestive rather than restrictive. The notion of a SKOS concept is useful when describing the conceptual or intellectual structure of a system of organization of knowledge, and when referring to specific ideas or meanings established within a KOS (W3C, 2009). For this research the conceptual structure is designated: Digital Library Domain Ontology and the SKOS representation is shown below and part of its structure as well in figure 24.

```
<Digital Library Ontology Domain> rdf:type skos:Concept
```

```
<skos:hasConcept rdf:resource=" Digital_Library_Ontology_Domain "/>
```

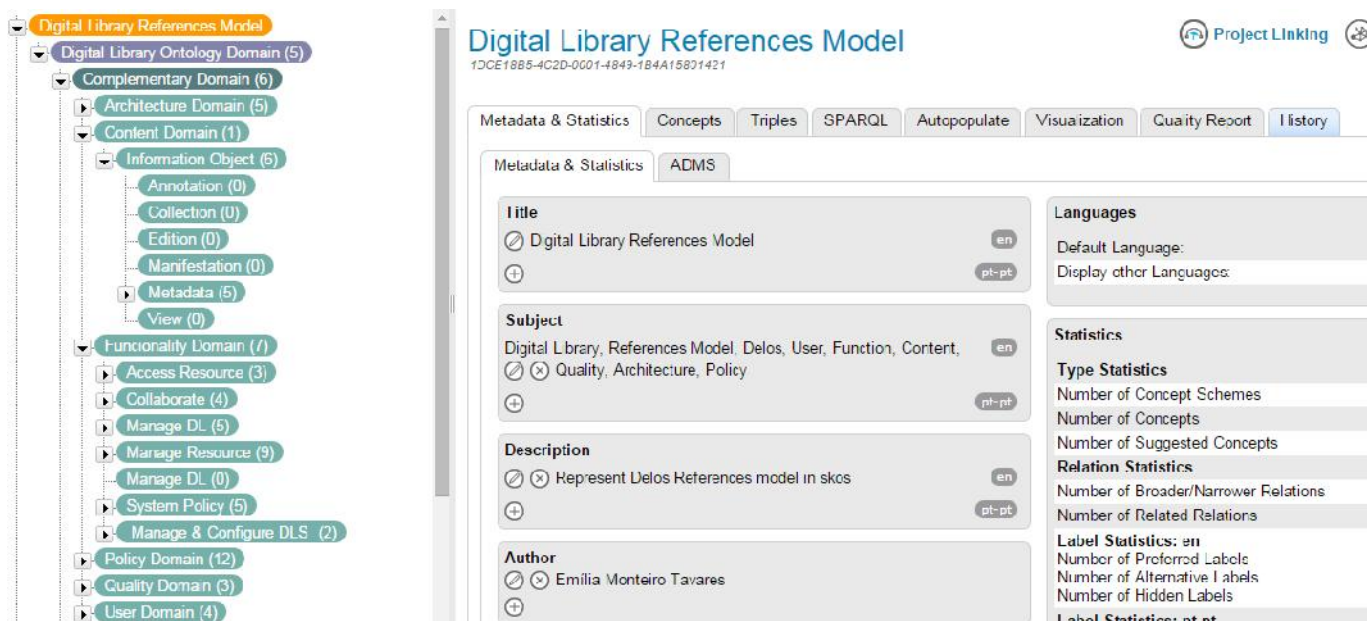


Figure 24 - Digital Library Ontology Domain concepts in PoolParty

Still, the classes and or concepts can have designated SKOS concept scheme and can be seen as an aggregation of one or more SKOS concepts. Semantic relationships (links) between these

concepts may also be seen as part of a scheme. These can be: skos: hasTopConcept skos: topConceptOf, skos: ConceptScheme, skos: inScheme.

Our top concepts are represented as:

```
<skos:hasTopConcept rdf:resource="Organisation_Domain"/>
```

```
<skos:hasTopConcept rdf:resource="Complementary_Domain"/>
```

```
<skos:hasTopConcept rdf:resource=" Digital_Library"/>
```

```
<skos:hasTopConcept rdf:resource="Digital_Library_System"/>
```

```
<skos:hasTopConcept rdf:resource="Digital_Library_Management_System"/>
```

Identifiers

Are necessary so that each concept can be identified in a unique way to avoid any ambiguity; the identifiers are introduced by a specific RDF property: Resources is rdf:resource. For example:

```
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/  
Digital_Library "/>
```

```
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib  
rary_System_"/>
```

```
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib  
rary_Management_System"/>
```

More resources identifiers can be seen in the annex, entitled RDFS file.

Notations

Preferred label is a skos:prefLabel - property corresponds to the notion of descriptor from the standards for the elaboration of the ontology. As we can see for each one concept we have the prefLabel:

```
<skos:prefLabel xml:lang="en">Organisation Domain</skos:prefLabel>
```

```
<skos:prefLabel xml:lang="en">Digital Library System</skos:prefLabel>
```

```
<skos:prefLabel xml:lang="en">Function</skos:prefLabel>
```

```
<skos:prefLabel xml:lang="en">Metadata</skos:prefLabel>
```

```
<skos:prefLabel xml:lang="en">Resource</skos:prefLabel>
```

More notation can be seen in the annex, entitled RDFS file.

Relations

Semantic relations are connections between different concepts. These semantic relations play a crucial role for defining concepts and there are two different categories of semantic relation:

- Hierarchical:
 - Narrower is a `skos:narrower` - used to assert that a concept has a more specific meaning;

```
<skos:narrower rdf:resource="User"/>
```

```
<skos:narrower rdf:resource="Function"/>
```

```
<skos:narrower rdf:resource="Content "/>
```

```
<skos:narrower rdf:resource="Policy"/>
```

```
<skos:narrower rdf:resource="Quality"/>
```

```
<skos:narrower rdf:resource="Architecture"/>
```

All these six narrowers presented here belong to Complementary Domain.

- Broader is a `skos:broader` - property is used to assert that a concept has more general meaning;

```
<skos:broader rdf:resource="Complementary_Domain"/>
```

```
<skos:broader rdf:resource="Organisation_Domain"/>
```

```
<skos:broader rdf:resource="Digital_Library"/>
```

- Associative:
 - Relates is a `skos:related` – it is used to assert an associative link between two concepts;

`<skos:related rdf:resource="Search"/>`

This relation can mean that:

- Search `<isa>` Access Resource
- Search `<issue>` Query
- Search `<return>` Result Set

`<skos:related rdf:resource="Manage_Resource"/>`

This relation can mean that:

- Manage Information Object `<isa>` Manage Resource
- Manage Actor `<isa>` Manage Resource
- Manage Function `<isa>` Manage Resource
- Manage Policy `<isa>` Manage Resource
- Manage Quality Parameter `<isa>` Manage Resource
- Create `<isa>` Manage Resource
- Update `<isa>` Manage Resource
- Validate `<isa>` Manage Resource
- Submit `<isa>` Manage Resource
- Withdraw `<isa>` Manage Resource
- Annotate `<isa>` Manage Resource
- Appraise `<isa>` Manage Resource
- Preserve `<isa>` Manage Resource

`<skos:related rdf:resource="Access_Resource"/>`

This relation can mean that:

- Access Resource `<isa>` Function
- Access Resource `<retrieve>` Resource

<skos:related rdf:resource="Policy_Domain"/>

This relation can mean that:

- Digital Library <definedBy> Policy Domain
- Digital Library System <definedBy> Policy Domain
- Digital Library Management System <definedBy> Policy Domain
- Policy Domain <consistOf> Policy

<skos:related rdf:resource="Resource"/>

- Resource <hasPart> Resource;
- Resource is <associatedTo> Resource for a certain Purpose;
- Resource <hasFormat> Resource Format;
- Resource <hasMetadata> Information Object;
- Resource <hasAnnotation> Information Object to a certain Region;
- Resource may be regulated by (<regulatedBy>) Policy;
- Resource may have (<hasQuality>) Quality Parameter;

More relations can be seen in the annex entitled RDFS file.

Statistically, this reference model in SKOS was represented with 1 concept scheme, 239 concepts, 236 and 918 Narrower and Broader relationships, as shown below in the figure 25.

Statistics	
Type Statistics	
Number of Concept Schemes	1
Number of Concepts	239
Number of Suggested Concepts	0
Relation Statistics	
Number of Broader/Narrower Relations	236
Number of Related Relations	918
Label Statistics: en	
Number of Preferred Labels	239
Number of Alternative Labels	7
Number of Hidden Labels	0
Label Statistics: pt-pt	
Number of Preferred Labels	6
Number of Alternative Labels	0
Number of Hidden Labels	0
Label Statistics: Total	
Number of Preferred Labels	245
Number of Alternative Labels	7
Number of Hidden Labels	0

Figure 25 – Statistics page in PoolParty

Conclusion and future work

In this thesis we have studied the DELOS Digital Library Reference Model (DLRM) in detail, with the aim to produce an ontology for the DLRM using SKOS. Two different approaches has been taken to produce de DLRM, first understand the DLRM in detail and compare it with other models and second represent it in SKOS.

The SKOS data model provides a standard way of migration featuring low cost for porting existing knowledge organization for the Semantic Web systems. SKOS also provides a lightweight, intuitive language for developing and sharing new knowledge organization systems(W3C, 2009).

The main conclusion is that DLRM Vocabulary does have potential as a description profile for digital libraries. SKOS also, is a good standard for representing and publishing Knowledge Organization Systems (KOS) on the Web, using a vocabulary and data model expressing Knowledge Organization Systems (KOS's) because SKOS can be expanded and take part in the much more general logical processes of the Semantic Web, used jointly with OWL. This would then offer a high level of flexibility at the descriptive formalisation level. For this reason some organization like: ACM for publish the new version of its Computing Classification System; STW Thesaurus for Economics thesaurus in SKOS that provides a vocabulary on any economic subject with more than 6,000 standardized subject headings and 190,000 entry terms and also The Library of Congress;The New York Times subject; The Food and Agriculture Organization of the United Nations (FAO), use SKOS for represent knowledge.

But, it was found that in terms of relations exists a generalization of relations without specifying what kind of relationship exists between two concepts, just they are related.

Digital Library references model

Digital libraries need a Reference Model to consolidate the diversity of existing approaches into a cohesive and consistent whole, to offer a mechanism for enabling the comparison of different DL systems, to provide a common basis communication within the DL community, and to help focus further advancement in this area (Candela et all, 2011).

Ontologies are a powerful tool for describing complex scenarios of use such as a DL, where several concepts and relationships between these concepts can be identified and formally represented.

The use of ontologies promotes the integration of new services into existing ones, and the interoperability with other systems through the appropriate semantic web services. New system functionalities and requirements can be added by including the appropriate description into the ontology framework that defines the DL scenario of use (Ferran & Minguillón, 2005).

Currently the trend of using ontologies can be identified in digital libraries, due to ease of processing and manipulation of information stored in digital format. However, nothing prevents such an application is extended to conventional libraries. What can predict with a high degree of certainty is that the library of the future will not be the same as the current one, so that many professional activities as we know them may become extinct. If this does not happen, the teaching of new skills is necessary for representation of content in digital environments (Ramalho, 2010).

The development of ontologies in the area of digital libraries incorporates new computational subsidies for representing the relationships between concepts, contributing to improvements in the representation, classification and indexing activities, and provides contextualizing the domain in which a document is inserted.

Future work

In this study, we presented the ontology for Delos References Model and tried to justify a methodology and design the intended functions. We assume that the applied methodology and the more abstract levels of the model have validity for further work in this field and also, give a huge contribution to the definition of an "ideal model" for digital libraries as well as serve as a contribution to enrich existing ontologies.

The presented ontology is the result of on-going work, and future work can also address and much more can be done, because there is a need to examine various DL initiatives using either of these two models (Delos reference Model or 5s) as a framework for better understanding of patterns of DL initiatives.

References

Abrizah, A., & Zainab, A. (2004). Bringing the Digital Library Design into the Realm of Enterprise Architecture. From. <http://cdn.intechopen.com/pdfs-wm/14696.pdf>

Agosti, M.; Candela, L.; Castelli, D.; Ferro, N.; Ioannidis, Y.; Koutrika, G.; Meghini, C.; Pagano, P.; Ross, S.; Schek, H.-J.; Schuldt, H. (2006). Deliverable D1.4.2 – A Reference Model for Digital Library Management Systems. Interim Report. From <http://146.48.87.21/OLP/UI/1.0/Disseminate/1413211158MQOiWaa9uu/a2214132111584cjjl6Tc> access in 01/10/2014

Ahmed , M.; Nandekar, U. (2012). Emerging forms of Copyright Licensing in the Digital Era. from <file:///D:/Downloads/SSRN-id2206768.pdf>

Alatrish, E. (2012). Comparison of Ontology Editors. eRAF Journal on Computing, vol.4. From: http://joc.raf.edu.rs/4/k_0020.pdf access in 21/09/2014

Alatrish, E. (2013). Comparison Some of Ontology Editors. Management Information Systems, Vol. 8 (2013), No. 2, pp. 018-024. From: <http://www.ef.uns.ac.rs/mis/archive-pdf/2013%20-%20No2/MIS2013-2-4.pdf> access in 21/09/2014

Alemu, G., Stevens, B., & Ross, P. (2012). Towards a conceptual framework for user-driven semantic metadata interoperability in digital libraries: A social constructivist approach. New Library World, Vol.113, No. 1/2, pp 38-54. Access in <http://eprints.rclis.org/16556/1/Towards%20a%20conceptual%20framework%20for%20user-driven%20semantic%20metadata%20interoperability%20in%20digital%20libraries.pdf>

Almeida, M. and Bax, M. (2003). Uma visão geral sobre ontologias: pesquisa sobre definições, tipos, aplicações, métodos de avaliação e de construção. <http://www.scielo.br/pdf/ci/v32n3/19019.pdf>

Athanasopoulos G., L. Candela, D. Castelli, P. Innocenti, Y. Ioannidis, A. Katifori, A. Nika, G. Vullo, S. Ross, (2010) The Digital Library Reference Model version 1.0, DL.org: Coordination Action on Digital Library Interoperability, Best Practices and Modelling Foundationsl. From

<http://bscw.research-infrastructures.eu/pub/bscw.cgi/d222816/D3.2b%20Digital%20Library%20Reference%20Model.pdf>. Access in 05/03/2014

Baker, T.; Bechhofer, S.; Isaac, A.; Miles, A.; Guus, S.; Summers, E. (2013). Key Choices in the Design of Simple Knowledge Organization System (SKOS). From: <http://arxiv.org/pdf/1302.1224v1.pdf> access in 22/09/2014

Berners-Lee, T. (1997). Axioms of Web Architecture: Metadata. Access in <http://www.w3.org/DesignIssues/Metadata.html> 05/032014

Bloehdorn, S.; Cimiano, P.; Duke, A.; Haase, P.; Heizmann, J.; Thurlow, I. and Volker, J. (2007). Ontology-based Question Answering for Digital Libraries. From <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.167.1228&rep=rep1&type=pdf> access in 05/03/2014

Borgaman, C. (1999). What is digital libraries? Competing visions. Information Processing and Management 35, 227-243. from https://www.ischool.utexas.edu/~i385d/readings/Borgman-1999-What_Are_Digital_Libraries.pdf 05/032014

Boyce, S., & Pahl, C. (2007). Developing Domain Ontologies for Course Content. Educational Technology & Society, 10 (3), 275-288. From http://www.ifets.info/journals/10_3/19.pdf access in 20/10/2014

Candela, L.; Castelli, D.; Fuhr, N.; Ioannidis, Y.; Klas, C.P.; Pagano, P.; Ross, S.; Saidis, C.; Schek, H.-J.; Schuldt, H.; Springmann, M. (2006). Deliverable D.1.4.1 - Current Digital Library Systems: User Requirements vs Provided Functionality. From <http://146.48.87.21/OLP/UI/1.0/Disseminate/1413210926woxNbWHopb/a221413210926n38GJVaR> access in 01/10/2014

Candela, L.; Castelli, D. and Pagano, P. (2009). On-demand Virtual Research Environments and the Changing Roles of Librarians. From http://www.d4science.eu/files/docs/lht27/lht_preprints.pdf access 21/05/2014

Casarosa, V. (2010). A Conceptual Model for Digital Libraries. Elag 2007 Conference, Barcelona, From <http://elag2007.upf.edu/papers/casarosa.pdf> Access in 23/05/2014

Castañeda, V.; Ballejos, L.; Caliusco, M.; & Galli, M. (2010). The Use of Ontologies in Requirements Engineering. *Global Journal of Researches in Engineering*, Vol. 10 Issue 6 (Ver 1.0) November 2010 From: globaljournals.org/GJRE_Volume10/1-The-Use-of-Ontologies-in-Requirements-Engineering.pdf access in 20/10/2014

Chapel Hill, USA, June 15, 2006. From

[https://www.academia.edu/986643/Context for Content Shaping Learning Objects and Modeling a Domain Ontology from the Teachers Perspective](https://www.academia.edu/986643/Context_for_Content_Shaping_Learning_Objects_and_Modeling_a_Domain_Ontology_from_the_Teachers_Perspective). Access in 29/06/2014

Controlled vocabulary (2015). *Wikipedia, the free encyclopedia* . From http://en.wikipedia.org/wiki/Controlled_vocabulary. Access in 20/02/2015

Corcho, O.; Fernández-López, M.; Gómez-Pérez, A. (2003). Methodologies, tools and languages for building ontologies. Where is their meeting point? *Data & Knowledge Engineering* 46 (2003) 41–64. From <http://oa.upm.es/2637/1/JCR02.pdf> access in 21/09/2014

Corcho, O.; Fernández-López, M.; Gómez-Pérez, A.; Gómez-Cima, A. (2002). Building legal ontologies with METHONTOLOGY and WebODE. From http://www.researchgate.net/publication/221467177_Building_Legal_Ontologies_with_METHONTOLOGY_and_WebODE/links/0fcfd50b23ad62f515000000 access in 15/09/2014

Cox, S.; Yua, J. and Rankine, T. (2014). SIVSoc: A Linked Data API for access to SKOS vocabularies. From <http://semantic-web-journal.org/system/files/swj880.pdf> access in 27/05/2015

Creative Commons. (2014). *Wikipedia, the free encyclopedia*. Access in http://en.wikipedia.org/wiki/Creative_Commons. Access in 15/09/2014

Delos (2013). A Reference Model for Digital Library Management Systems. http://www.delos.info/index.php?option=com_content&task=view&id=345

Digital library (2014). *Wikipedia, the free encyclopedia*. From http://en.wikipedia.org/wiki/Digital_library#The_future Access in 20/04/2014

Digital Library. (2014). *Wikipedia, the free encyclopedia*. Access in http://en.wikipedia.org/wiki/Digital_library

- DLF (1998). A working definition of digital library. From <http://old.diglib.org/about/dldefinition.htm>
- European Union (2013). Challenges for copyright in the digital era - copyright for 2020. from http://www.filmjus.hu/0_hirek/Informal%20Council%20Copyright%20doc%20FINAL.pdf
- Exploratory Research. (2014). *Wikipedia, the free encyclopedia*. Access in http://en.wikipedia.org/wiki/Exploratory_research
- Farquhar, A. (2009). What is Case Study Research? From http://www.sagepub.com/upm-data/46240_Farquhar.pdf access in 20/09/2014
- Ferran, N. and Minguillón, E. (2005). Towards personalization in digital libraries through ontologies. *Library Management* Vol. 26 No. 4/5, 2005 pp. 206-217. From http://eprints.rclis.org/9179/1/nferranf_LMJ.pdf access in 26/05/2014
- Fox, E. (1999). The Digital Libraries Initiative: Update and Discussion. From <http://www.asis.org/Bulletin/Oct-99/fox.html> access in 26/05/2014
- Fox, E. (2006). 5S and the Reference Model. *DELOS Reference Model Workshop Frascati Rome*. from http://www.delos.info/files/pdf/events/referencemodel_june06/Presentations/5S_Model_Fox.pdf access in 20/08/2014
- Fox, E., Suleman, H., Madalli, D., Cassel, L. (2003). Digital Libraries. Practical Handbook of Internet Computing, CRC. From: <http://pubs.cs.uct.ac.za/archive/00000016/01/handbook16.pdf> access in 20/08/2014
- Gamage, R. (2013). An Ontology Based Fully Automatic Document Classification System Using an Existing Semi-Automatic System, from: <http://library.ifla.org/159/1/112-wijewickrema-en.pdf> access in 26/05/2014 access in 09/06/2014
- Gonçalves, M. (2004) Streams, Structures, Spaces, Scenarios, and Societies (5S): A Formal Digital Library Framework and Its Applications. From <http://scholar.lib.vt.edu/theses/available/etd-12052004-135923/unrestricted/MarcosDissertation.pdf>

- González, R. (2005). A Semantic Web approach to Digital Rights Management. From <http://rhizomik.net/html/~roberto/thesis/Thesis.pdf> access in 15/08/2014
- Greenberg, J. (2005). Understanding Metadata and Metadata Schemes. Access in <http://www.ils.unc.edu/mrc/pdf/greenberg05understanding.pdf>
- Hanna, K. (2013). Library of Congress Archives 170 Billion Tweets in Big Data Bonanza. From <http://midsizeinsider.com/en-us/article/library-of-congress-archives-170-billion>
- Harvey, R. (2005). [Preserving digital materials](#). The American Archivist, Vol. 75 (Fall/Winter 2012): 567–587. from http://www2.archivists.org/sites/all/files/AAv075_FallWinter2012_REVIEWS.pdf
- Harzallah, M. (2004). Ontology of Enterprise Competencies. From. <http://ceur-ws.org/Vol-125/paper20.pdf> access in 29/06/2014
- Haslhofer, B.; Martins, F. and Magalhães, J. (2013). Using SKOS Vocabularies for Improving Web Search. *International World Wide Web Conference Committee (IW3C2)*. From <http://www2013.w3c.br/companion/p1253.pdf> access in 23/09/2014
- Hedstrom, M. (1998). Digital preservation: a time bomb for Digital Libraries. From http://107.21.246.134/wilbur/wp-content/uploads/2014/01/smg110_LIS2610_Assignment_1_Part_1-PDF.pdf
- Hooper, R. (2012). Digital Copyright Exchange Feasibility Study. from <http://www.ipo.gov.uk/dce-report-phase1.pdf>
- Innocenti, P., Smith, M., Ashley, K., Ross, S., Robbio, A., Pfeiffenberger, H., & Faundeen, J. (2011). Towards a holistic approach to policy interoperability in digital libraries and digital repositories. *The International Journal of Digital Curation Issue 1, Volume 6 | 2011*. From <http://www.ijdc.net/index.php/ijdc/article/view/167/235>. Access in 08/05/2014
- Isaac, A. (2011). SKOS. Simple Knowledge Organization System. From <http://dcevents.dublincore.org/IntConf/dc-2011/paper/view/69/36> access in 08/06/2014
- Isah, A.; Mutshewa, A.; Serema, B. & Kenosi, L. (2013). Digital Libraries: Analysis of Delos Reference Model and 5S Theory. *J. of infosci. theory and practice* 1(4): 38-47, 2013. *Journal of*

Information Science Theory and Practice. From

<http://acoms.kisti.re.kr/notReviewEpaperFile.do?method=finalDown&journalSeq=J000043&issueSeq=257&serviceEpaperSeq=1007> access in 21/05/2014

Jupp, S.; Bechofer, S. & Stevens, R. (2009). A Flexible API and Editor for SKOS. From

http://ftp.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-401/iswc2008pd_submission_88.pdf access in 20/10/2014

Kalibatiene, D. and Vasilecas, O. (2011). Survey on Ontology Languages. (Eds.): BIR 2011, LNBIP 90, pp. 124–141 From:

<http://202.154.59.182/mfile/files/Information%20System/Perspectives%20in%20Business%20Informatics%20Research%3B%2010th%20BIR%202011/Chapter%2010%20Survey%20on%20Ontology%20Languages.pdf> access in 21/09/2014

Kelapure, R.; Gonçalves, M.; Fox, E. (2004). Scenario-Based Generation of Digital Library Services. From http://homepages.dcc.ufmg.br/~mgoncalv/DLCourse/ecdl_rohit8.pdf

Kohlbacher, F. (2006). The Use of Qualitative Content Analysis in Case Study Research.

Volume 7, No. 1, Art. 21 – January 2006. From <http://www.qualitative-research.net/index.php/fqs/article/%20view/75/153January%202006> access in 15/09/2014

Kozievitch, N. (2009). Complex Objects in Digital Libraries. Proc. of Joint Conference on Digital Libraries. From

http://webcache.googleusercontent.com/search?q=cache:cmiNgQjRY_EJ:www.lis.ic.unicamp.br/publications/journal-and-conference-papers/complex-objects-in-digital-libraries/at_download/file+&cd=9&hl=pt-PT&ct=clnk&gl=cv

L. Candela, G. Athanasopoulos, D. Castelli, K. El Raheb, P.

Innocenti, Y. Ioannidis, A. Katifori, A. Nika, G. Vullo, S. Ross C. Thanos (2011). D3.2b The Digital Library Reference Model. from <https://www.coar-repositories.org/files/D3-2b-Digital-Library-Reference-Model.pdf> Access in 21/05/2014

La Fuente, G. (2008). The Simple Knowledge Organization System (SKOS) A situation report for the HIVE Project. From:

https://www.nescent.org/wg/hive/images/2/2e/SKOS_report_for_HIVE-version1-0.pdf access in 22/09/2014

Lascata, J.; Nogueras-Iso, J.; López-Pellicer, F.; Muro-Medrano, P.; and Zarazaga-Soria, F. (2007). ThManager: An Open Source Tool for Creating and Visualizing SKOS. Information Technology and Libraries. From

<https://136.167.2.46/ojs/index.php/ital/article/viewFile/3274/2887> access in 01/10/2014

Lebbink, H. and Witteman, C. (2002). Ontology-Based Knowledge Acquisition for Knowledge Systems. From <http://www.computerscience.nl/groups/IS/archive/henkjan/lebbink02a.pdf>. Access in 29/06/2014

Lenzerini, M.; Milano, D.; Poggi, A. (2004) State of the Art Report. From <http://wwwusers.di.uniroma1.it/~estrinfo/1%20Ontology%20representation.pdf> Access in 25/02/2014

LibWeb (2014). Library Servers via WWW from <http://www.lib-web.org/>

Linked Data (2015). *Wikipedia, the free encyclopedia*. From http://en.wikipedia.org/wiki/Linked_data access in 28/05/2015

López. M. (1999). Overview of methodologies for building ontologies. Proceedings of the IJCAI-99 workshop on Ontologies and Problem-Solving Methods (KRR5) Stockholm, Sweden, August 2, 1999. From <http://www.lsi.upc.edu/~bejar/aia/aia-web/4-fernandez.pdf> Access in 22/09/2014

McGuinness, D. (2003). Ontologies Come of Age. From <http://www-ksl.stanford.edu/people/dlm/papers/ontologies-come-of-age-mit-press-%28with-citation%29.htm> access in 29/06/2014

McLeod, D. (2006). Ontology Development Tools for Ontology- Based Knowledge Management. From: http://research.create.usc.edu/cgi/viewcontent.cgi?article=1104&context=nonpublished_reports access in 21/09/2014

McNamee, J.; Fiedler, M. (2007). Copyright: challenges of the digital era. from http://www.edri.org/files/paper07_copyright.pdf

Merrill, S.; Raduche, W. (2013) Copyright in the Digital Era: Building Evidence for Policy. from <http://www.ip-watch.org/weblog/wp-content/uploads/2013/05/NRC-Copyright-in-the-Digital-Era-FINAL-Apr-2013.pdf>

Metadata. (2014). *Wikipedia, the free encyclopedia*. Access in <http://en.wikipedia.org/wiki/Metadata>

Miles, A. (2008). The Web and SKOS. From http://www.iskouk.org/presentations/miles_web_and_skos_200807.pdf access in 08/06/2014

Mizoguchi, R. (W/D). Ontology development, tools and languages. From http://www.unipamplona.edu.co/unipamplona/portaIG/home_23/recursos/general/06032011/onto_parte2.pdf. Access in 21/09/2014

Morais, E. and Ambrósio, A. (2007). Ontologias: Conceitos, usos, tipos, metodologias, ferramentas e linguagem. http://www.inf.ufg.br/sites/default/files/uploads/relatorios-tecnicos/RT-INF_001-07.pdf

Muir, A. (2003). Copyright and licensing issues for digital. Preservation and possible solutions. from <http://elpub.scix.net/data/works/att/0315.content.pdf>

Murthy, U.; Gorton, D.; Torres, R.; Gonçalves, M.; Fox, E.; Delcambre, L. (2007). Extending the 5S Digital Library (DL) Framework: From a Minimal DL towards a DL Reference Model. *First International Workshop on "Digital Libraries Foundations" Vancouver, British Columbia, Canada, June 23, 2007*. From <http://www.dlib.vt.edu/projects/5S-Model/extending5S.pdf>

Nguyen, H. (2013). Trends in digital library research : a knowledge mapping and ontology engineering approach. From <https://opus.lib.uts.edu.au/research/bitstream/handle/10453/24113/02whole.pdf?sequence=2> access in 20/02/2014

Noy, N. & McGuinness, D. (2001). Ontology Development 101: A Guide to Creating Your First Ontology. From http://protege.stanford.edu/publications/ontology_development/ontology101.pdf access in 20/10/2014

Ohren, P. (2009). The DELOS Digital Library Reference Model as a basis for describing and evaluating search systems. <https://oda.hio.no/jspui/bitstream/10642/320/2/Ohren.pdf> access in 20/02/2014

Ongus, Raymond W. and Nyamboga, Constantine M. (2004). “Digitizing a research library: Egerton University – Kenya”. SRELS Journal of Information Management. Vol. 41 (No.2) from http://drtc.isibang.ac.in/xmlui/bitstream/handle/1849/401/paper_kemparaju.pdf?sequence=1

Ontology language. (2014). *Wikipedia, the free encyclopedia*. Access in http://en.wikipedia.org/wiki/Ontology_language

Pattuelli, C. (2006). Context for Content: Shaping Learning Objects and Modeling a Domain Ontology from the Teacher's Perspective. *First International Workshop, DL-CUBA 2006*

PoolParty (2015). *Wikipedia, the free encyclopedia*. From <https://www.w3.org/2001/sw/wiki/PoolParty> access in 27/05/2015

Putkey, T. (2011). Using SKOS to Express Faceted Classification on the Semantic Web. From: <http://www.webpages.uidaho.edu/~mbolin/putkey.pdf> access in 22/09/2014

Reference model. (2014). *Wikipedia, the free encyclopedia*. Access in http://en.wikipedia.org/wiki/Reference_model

Roussey, C. (2005). Guidelines to build ontologies: A bibliographic study. Technical Report n°1. From <http://www.towntology.net/Documents/guidelines.pdf> access in 30/09/2014

Rowlands, I. & Bawden, D. (1999). Digital Libraries: A Conceptual Framework. *Libri, 1999, vol. 49, pp. 192–202*. From <http://www.librijournal.org/pdf/1999-4pp192-202.pdf>

Saracevic, T. (2004). How were digital libraries evaluated? Paper presented at the DELOS WP7 Workshop on the Evaluation of Digital Libraries. Retrieved May, 2011 from http://comminfo.rutgers.edu/~tefko/DL_evaluation_LIDA.pdf

Sawsaa, A. and Lu, J. (2014). Building an Advance Domain Ontology Model of Information Science (OIS). *International Journal of Digital Information and Wireless Communications (IJDWC) 4(2): 90-98. The Society of Digital Information and Wireless Communications, 2014*

(ISSN: 2225-658X) From

http://webcache.googleusercontent.com/search?q=cache:O73_pqsSW64J:sdiwc.net/digital-library/building-an-advance-domain-ontology-model-of-information-science-ois+&cd=2&hl=pt-PT&ct=clnk&gl=cv access in 09/06/2014

Schandl, T. and Blumauer, A. (2010). PoolParty: SKOS Thesaurus Management utilizing Linked Data. From <http://www.poolparty.biz/wp-content/uploads/2013/04/PoolParty-SKOS-Thesaurus-Management-utilizing-Linked-Data.pdf> access in 27/05/2015

Schwartz, C. (2000). Digital libraries an overview. *The Journal of Academic Librarianship*, Volume 26, Number 6, pages 385–393. From <http://home.kku.ac.th/hslib/malee/412725/document/DLOverview.pdf>

Shen, R. (2006). Applying the 5S Framework To Integrating Digital Libraries. Form http://scholar.lib.vt.edu/theses/available/etd-04212006-135018/unrestricted/Rao_finalDefense_final5.pdf

Shen, R.; Fan, W.; Torres, R.; Fox, E. (2006). Exploring Digital Libraries: Integrating Browsing, Searching, and Visualization. From <http://www.lis.ic.unicamp.br/publications/docs/exploringdigital.pdf>

Sheth, A.; Ramakrishnan, C. and Thomas, C. (2005). Semantics for the Semantic Web: The Implicit, the Formal and the Powerful. <http://lsdis.cs.uga.edu/library/download/SRT05-IJ-SW-IS.pdf>

Shiri, A. (2003). Digital library research: current developments and trends. from <http://eprints.rclis.org/4905/1/ASLRcolumn.pdf> Access in 19/03/2014

Simple Knowledge Organization System (2015). *Wikipedia, the free encyclopedia* . From http://en.wikipedia.org/wiki/Simple_Knowledge_Organization_System#Concepts. Access in 20/02/2015

Soergel, D. (2002). Thesauri and ontologies in digital libraries. *Joint Conference on Digital Libraries*. From. <http://www.dsoergel.com/cv/B63.pdf>. Access in 29/06/2014

Spasser, M. (2002). Realist Activity Theory for Digital Library Evaluation: Conceptual Framework and Case Study. *Computer Supported Cooperative Work* 11: 81– 110. Access in <http://www.ics.uci.edu/~redmiles/activity/final-issue/Spasser/Spasser.pdf>

Suárez-Figueroa, M.; Gómez-Pérez, A.; VillazónTerrazas, B. (2009). How to write and use the Ontology Requirements Specification Document. Form <http://delicias.dia.fi.upm.es/wiki/images/b/b0/ORequirementsSpecification.pdf> access in 20/10/2014

Tang, J.; Wang, B.; Zhang, J. (2012). A Unified Probabilistic Framework for Name Disambiguation in Digital Library. *IEEE transactions on knowledge and data engineering*, vol. 24, no. x. Access in <http://keg.cs.tsinghua.edu.cn/jietang/publications/TKDE12-Tang-Name-Disambiguation.pdf>

Taxonomy (2015). *Wikipedia, the free encyclopedia*. from <http://en.wikipedia.org/wiki/Taxonomy>. access in 20/02/2015

Thesaurus (2015). *Wikipedia, the free encyclopedia*. From <http://en.wikipedia.org/wiki/Thesaurus>. access in 20/02/2015

Trust, J. (2009). Glossary and Bibliography for Controlled Vocabularies. From https://www.getty.edu/research/tools/vocabularies/glossary_vocabs.pdf access in 20/02/2015

Tudorache, T.; Nyulas, C.; Noy, N. and Musen, M. (2011). WebProtégé: A Collaborative Ontology Editor and Knowledge Acquisition Tool for the Web. *Semantic Web* 11-165 (2011). From. http://www.semantic-web-journal.net/sites/default/files/swj210_1.pdf. Access in 07/07/2014

U.S. Congress (1989). Copyright and Home Copying: Technology Challenges the Law. U.S. Congress, Office of Technology Assessment, OTA-CIT-422 (Washington, DC: U.S. Government Printing Office. from http://govinfo.library.unt.edu/ota/Ota_2/DATA/1989/8910.PDF

Verma, N. & Dominic, J. (2009) Digital libraries: definitions, issues and challenges in modern era. *Journal of Lib. Inf. & Comm. Technology* Vol. 1 No.1. from http://escienceworld.net/admin/editor/filemanager/connectors/php/files/1_5%281%29.pdf

- Vullo, G. (2010). A Global Approach to Digital Library Evaluation. from <https://liber.library.uu.nl/index.php/lq/article/view/URN%3ANBN%3ANL%3AUI%3A10-1-113589/8300>
- W3C (2009). SKOS Simple Knowledge Organization System Reference. From <http://www.w3.org/TR/skos-reference/> access in 01/10/2014
- W3C. (2009). SKOS Use Cases and Requirements. From <http://www.w3.org/TR/2009/NOTE-skos-ucr-20090818/> access in 08/06/2014
- Yin, R. (2009). Case Study research design and methods. (4rd ed., vol. 5). From http://cemusstudent.se/wp-content/uploads/2012/02/YIN_K_ROBERT-1.pdf access in 20/09/2014
- Youn, S.; Arora, A.; Chandrasekhar, P.; Jayanty, P.; Mestry, A. and Sethi, S. (2009). Survey about Ontology Development Tools for Ontology based Knowledge Management. From: <http://suanpalm3.kmutnb.ac.th/teacher/FileDL/supot22255310501.pdf> access in 29/06/2014
- Yun, H.; Xu, J.; Xiong, J. and Wei, M. (2013). A knowledge engineering approach to develop domain ontology. From <http://www.irma-international.org/viewtitle/68751/> access in 15/09/2014
- Zhang H. (2008). The Scale-Free Nature of Semantic Web Ontology. ACM 978-1-60558-085-2/08/04. From <http://www2008.wwwconference.org/papers/pdf/p1047-zhang.pdf> access in 15/09/2014
- Zhang, J. (2007). Ontology and the Semantic Web. *Proceedings of the North American Symposium on Knowledge Organization*. Vol. 1. From <https://journals.lib.washington.edu/index.php/nasko/article/download/12830/11311> access in 06/06/2014
- Zucker, D. (2009). Teaching Research Methods in the Humanities and Social Sciences. How to do case study research. School of Nursing Faculty Publication Series. Chapter 4. From http://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1001&context=nursing_faculty_publications access in 20/09/2014

A Appendix

Here we will present some examples of classes, properties and relations of the ontology that was created, the complete ontology is available in this link below:

<https://drive.google.com/open?id=0B7nIdhf3fVkJDcGZNRDY3bUNhQWs&authuser=0>

A.1 Digital Library References Model represent in SKOS

A.1.1 Digital Library Domain and their top concepts

```

<rdf:Description
rdf:about="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/_Digital_Library_Domain_">
  <rdf:type rdf:resource="http://www.w3.org/2004/02/skos/core#ConceptScheme"/>
  <dcterms:title xml:lang="en"> Digital Library Ontology Domain </dcterms:title>
  <rdfs:label xml:lang="en"> Digital Library Ontology Domain </rdfs:label>
  <dcterms:description
xml:lang="en"> comprises all the elements needed to represent the three systems of the digital
library universe</dcterms:description>
  <dcterms:creator xml:lang="en">Emília M. Tavares</dcterms:creator>
  <dcterms:subject xml:lang="en">Digital Library, </dcterms:subject>
  <dcterms:created
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-
20T17:28:07Z</dcterms:created>
  <skos:hasTopConcept
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Organisation_Domain"/>
  <skos:hasTopConcept
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Complementary_Domain"/>
  <skos:hasTopConcept
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Library"/>
  <skos:hasTopConcept
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Library_System_2"/>
  <skos:hasTopConcept
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Library_Management_System_2"/>
</rdf:Description>

```

A.1.2 Main Concepts

```

<skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Content_Domain"/>

```



```

    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/User_Domain"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Funcionalit
y_Domain"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Policy_Do
main"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Quality_Do
main"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Architectur
e_Domain"/>
<skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_D
omain"/>

```

A.1.3 Associative Relations

```

<skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Actor"/>
<skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib
rary"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib
rary_Management_System_2"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Collection"/
>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib
rary_System_2"/>
<skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_D
omain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Action"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Manage_Re
source"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Access_Res
ource"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Collaborate
"/>

```

```

    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Manage_DL"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Manage_Information_Object"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Architecture_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Component_Profile"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Library"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Library_Management_System_2"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Library_System_2"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_Identifier"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Actor_Profile"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Policy_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Manage & amp; Configure DLS "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital Rights Management Policy "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Architectural Component "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Software Architecture Component "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Software Component "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/System Architecture Component "/>

```

A.1.4 Hierarchical Relations

A.1.4.1 Digital Library

```

<rdf:Description
rdf:about="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Library">
    <rdf:type rdf:resource="http://www.w3.org/2004/02/skos/core#Concept"/>
    <skos:prefLabel xml:lang="en">Digital Library</skos:prefLabel>
    <skos:topConceptOf
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/_Digital_Library_Domain_"/>
    <dcterms:created
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-22T16:30:59Z</dcterms:created>
    <dcterms:creator>Emília M. Tavares</dcterms:creator>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Content_Domain"/>
    <dcterms:modified
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-27T16:32:54Z</dcterms:modified>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/User_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Actor"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Funcionalit_y_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Policy_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Quality_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Quality Parameter "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Architecture_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Information_Object"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Library_System_2"/>

```

```

    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_D
omain"/>
</rdf:Description>

```

A.1.4.2 Digital Library System

```

<rdf:Description
rdf:about="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Librar
y_System_2">
    <rdf:type rdf:resource="http://www.w3.org/2004/02/skos/core#Concept"/>
    <skos:prefLabel xml:lang="en">Digital Library System</skos:prefLabel>
    <skos:topConceptOf
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/_Digital_Li
brary_Domain_"/>
    <dcterms:created
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-
22T16:31:30Z</dcterms:created>
    <dcterms:creator>Emília M. Tavares</dcterms:creator>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Actor"/>
    <dcterms:modified
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-
27T16:35:02Z</dcterms:modified>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Funcionalit
y_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Policy_Do
main"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Quality_Do
main"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Quality Par
ameter "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Architectur
e_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib
rary"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_D
omain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Content_Do
main"/>

```

```

    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/User_Doma
in"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Software A
rchitecture "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/System Arc
hitecture "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib
rary_Management_System_2"/>
</rdf:Description>

```

A.1.4.3 Digital Library Management System

```

<rdf:Description
rdf:about="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Librar
y_Management_System_2">
    <rdf:type rdf:resource="http://www.w3.org/2004/02/skos/core#Concept"/>
    <skos:prefLabel xml:lang="en">Digital Library Management System</skos:prefLabel>
    <skos:topConceptOf
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/_Digital_Li
brary_Domain_"/>
    <dcterms:created
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-
22T16:31:38Z</dcterms:created>
    <dcterms:creator>Emília M. Tavares</dcterms:creator>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Content_Do
main"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Functionali
ty Policy "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/User_Doma
in"/>
    <dcterms:modified
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-
27T16:35:17Z</dcterms:modified>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Funcionalit
y_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Policy_Do
main"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Quality_Do
main"/>

```

```

    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Quality Par
ameter "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Architectur
e_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib
rary_System_2"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_D
omain"/>
</rdf:Description>

```

A.1.4.4 Resource

```

<rdf:Description
rdf:about="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource">
    <rdf:type rdf:resource="http://www.w3.org/2004/02/skos/core#Concept"/>
    <skos:prefLabel xml:lang="en">Resource</skos:prefLabel>
    <skos:broader
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_D
omain"/>
    <dcterms:created
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-
21T15:50:40Z</dcterms:created>
    <dcterms:creator>Emília M. Tavares</dcterms:creator>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_I
dentifier"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_F
ormat"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Query"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Ontology"/
>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_s
et"/>
    <dcterms:modified
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-
27T16:31:41Z</dcterms:modified>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_s
et"/>

```

```

    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Information
_Object"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Actor"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Action"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Actor_Profi
le"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Funcionalit
y_Domain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Create"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Access_Res
ource"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Quality Par
ameter "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Policy_Do
main"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Context"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_F
ormat"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Metadata"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Provenance
_2"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Acquire"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Visualise"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Change Ma
nagement Policy"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource M
anagement Policy"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Support Pol
icy "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Collection
Development Policy"/>

```

```

    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/License "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Preservation Policy "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Architectur al Component "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Software Ar chitecture Component "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Software C omponent "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/System Arc hitecture Component "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib rary"/>
</rdf:Description>

```

A.1.4.5 Information Object

```

<rdf:Description
rdf:about="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Information_O bject">
    <rdf:type rdf:resource="http://www.w3.org/2004/02/skos/core#Concept"/>
    <skos:prefLabel xml:lang="en">Information Object</skos:prefLabel>
    <skos:broader
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Content_Do main"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Edition"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/View"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Manifestati on"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Metadata"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_S et"/>
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Annotation" />
    <skos:narrower
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Collection"/ >

```



```

    <dcterms:modified
rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2015-05-
27T16:31:54Z</dcterms:modified>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource_D
omain"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Resource"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Ontology"/
>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Collection"/
>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Content_Do
main"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Action_log
_2"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Actor_Profi
le"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Context"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Actor"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Actor Profi
le"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Annotate"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Manage_Inf
ormation_Object"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Author"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Convert_to
_a_Different_Format"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Author Coll
aboratively "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Policy_Do
main"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Quality Par
ameter "/>

```

```

    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Edition"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/View"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Manifestati
on"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Metadata"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Provenance
_2"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Component
Profile"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Annotation"
/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Query"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Create"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Physically_
Convert"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Extract"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/ Collection
Development Policy"/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital Rig
hts "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Software C
omponent "/>
    <skos:related
rdf:resource="http://digitallibraryreferencesmodel/DigitalLibraryReferencesModel/Digital_Lib
rary"/>

```